# The End of Matter?
# On the Early Reception of Relativity in neo-Kantian Philosophy

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Paolo Pecere
University of Roma Tre

## 1. Introduction: Einstein's relativity, matter and field

The hypothesis that relativity theory entailed the rejection of the concept of matter was spelled out by Einstein in a number of places. The statements in the popular book "The evolution of physics", written with Leopold Infeld, are quite clear in this regard.

> "We cannot build physics on the basis of the matter-concept alone. But the division into matter and field is, after the recognition of the equivalence of mass and energy, something artificial and not clearly defined. Could we not reject the concept of matter and build a pure field physics? What impresses our senses as matter is really a great concentration of energy into a comparatively small space. We could regard matter as the regions in space where the field is extremely strong. In this way a new philosophical background could be created [...] There would be no place, in our new physics, for both field and matter, field being the only reality" (Einstein, Infeld 1938/1967, 257).

The "new philosophical background" was presented as a possible implication of physical discoveries. Notably, Einstein's relativity theory (both special and general) was presented as merely a part of this process. Indeed, general relativity did not entirely realize Einstein's idea of a "new physics"; it rather posited a new problem:

> "This new view is suggested by the great achievements of field physics, by our success in expressing the laws of electricity, magnetism, gravitation in the form of structure laws, and finally by the equivalence of mass and energy. Our ultimate problem would be to modify our field laws in such a way that they would not break down for regions in which the energy is enormously concentrated" (Ivi, 258).

Thus Einstein introduced relativity in a series of physical theories of field that culminated in the "programme" of a "pure field physics". The two achievements that suggested the need for a new breakthrough were the development of "structure laws" in classical and relativistic field theories and the "equivalence" of mass and energy. This suggested that mass – apparently coextensive with "matter" – might be also reduced to a property of a field in a new physical theory. As is well known, Einstein constantly believed that the continuity of fields and the discreteness of particles produced a "provisional and unsatisfactory" dualism in post-relativistic physics. After the rise of quantum mechanics produced a quite different background for the physics of matter, Einstein maintained that the need for a new field theory was not removed, and always considered quantum mechanics as a provisional theory. In a letter to Michele Besso of August 10 1952 he still argued for the need of a theory where particles are "deduced" rather than postulated (Einstein, Besso 1972, doc. n. 190). He worked until his last years on a pure field theory that would present particles (whether point-like or extended) as solutions of fields. However, Einstein never managed to realize this programme.[1]

Besides the open status of Einstein's late research programme, the interpretation and assessment of his views on field and matter are complicated by a number of further reasons. First, as it has been pointed out, Einstein's apparent identification of matter and mass in the above quoted passages, as well as his occasional talk of the substantial identity of mass and energy,[2] were problematic – although widely accepted among early interpreters – and still raise substantial interpretative issues.[3] Second, contemporary studies of "structure laws" in early 20th century physics are focused on different contributions, such as the "structural" epistemology of Poincaré and Cassirer or the programs of a unified field physics by Hermann Weyl and Arthur Eddington; then the application of group theory and the rise of quantum field theory have provided a different scientific background for successive investigations of these issues.[4] Indeed, assessments of "structuralism" and "structural realism" in contemporary philosophy of science are more indebted to these accomplishment than to Einstein's original theories, and Einstein himself is not considered a "structuralist" because he always believed in the existence of self-subsistent, independent physical objects (the deduction of discrete

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[1] On these research see Pais 1982, 312-313, 345-376, 488-497. Also see Einstein's own account in Schilpp 1949, in part. pp. 71-94.

[2] "Mass and energy are essentially alike. They are only different expressions for the same thing" (Einstein 1953, 45).

[3] For an outline of this problem, with useful historical remarks, see Lange 2002, ch. 6. Lange also quotes prominent scientists who accepted at face value Einstein's identification of mass and energy, e.g. Werner Heisenberg.

[4] For a history of these investigations in early relativistic physics (especially on Weyl and Eddington) see Ryckman 2005.

parts of matter from continuous fields being a different issue from the identification of objectivity in physics with pure structural relations).[5] On the whole, to consider Einstein's original views on field and matter in both a historical and theoretical perspective is hardly straightforward. In this paper, I will not deal with this problem. I will rather deal with early Neo-Kantian interpretations of relativity, focusing on the way Cassirer contextualized Einstein's theories in the historical narrative of modern science. I will start from two observations made by Cassirer: first, he correctly pointed out that a number of physical and philosophical theories had made the hypothesis that matter might be conceived as a product of a different dynamical concept (force, field, or energy) before the formulation of relativity, and thus provided a background for Einstein's programme of a post-relativistic field theory; second, Cassirer also pointed out that Weyl's and Eddington's interpretations of relativity dealt with the hypothesis of mass as a product of field (§ 2). In the light of this series of promising theories, Cassirer considered relativity as conducive to "pure field theory". At the same time, he also conceived this succession of theories as the confirmation of the hypothesis formulated by his teacher Hermann Cohen of a "dissolution of matter", as a progressive result of the history of physics (§§ 3–4). However, as I will argue, this hypothesis was motivated by a "Platonic", neo-Kantian epistemological programme that was foreign to Einstein's original views (§ 5). Cassirer subtly recognized that this programme agreed with a trend in relativistic theories of matter. However – as I will argue – he did not clearly recognize the open problems in these theories, which produced a substantial flaw in the epistemological project of Marburg neo-Kantianism, casting doubts on the conclusion that relativity prepared the "victory of idealism".

## 2. Cassirer on relativity and "field physics"

The idea of a physics without matter, formulated by Einstein in the above quoted account, predated the formulation of relativity theory. In the late 19th century, the electromagnetic theory of mass had been debated as a possible means of explaining matter away. In the article

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[5] "Structural realism", as the theory – or family of theories – that only the mathematical or structural content of scientific theories can be considered as their real ontological content, has been debated as an important version of scientific realism since at least the 1970s (Maxwell 1970; Worrall 1989. Cf. Ladyman 2020). However, early models of what is now called structural realism date back to the early 20th century. Cassirer, as we will see, played a major role in this early story (see Gower 2000). On the metaphysics of structural realism and Einstein's belief in individuals see Ladyman, Ross (2010), 148–154, in part. 151.

"The End of Matter" (originally published in 1906) Henri Poincaré had reported that according to many physicists "matter does not exist". However the issue was far from settled, and Poncairé immediately added: "this discovery is not conclusive" (Poincaré 1908, 282). The electromagnetic theory of mass never gained the status of a confirmed hypothesis.[6] It is no surprise that it was not even mentioned in the popular account of physical theories by Einstein and Infeld. Hence it might be argued that Einstein explored a new way of realizing the explanation of mass in terms of fields and thus fulfill the aim of the electromagnetic theory of mass. Nevertheless, the origin of his programme cannot be identified with this theory. The very idea of a dynamical explanation of mass predated the electromagnetic theory of mass as well, and Einstein himself, after the publication of special relativity, was familiar with a number of epistemological and scientific theories that mentioned this broader context.

A prominent example was Cassirer's neo-Kantian "critique of knowledge". In his book *Einstein's Theory of Relativity* (1921), Cassirer argued that general relativity was a "natural logical conclusion of an intellectual tendency characteristic of all the philosophical and scientific thought of the modern age" (SR 379). According to Cassirer, Einstein's theories demonstrated – against positivism – the active role of "physical thought" in the constitution of scientific objectivity:

> "The new concept of nature and of the object, which the theory of relativity establishes, is grounded in the form of physical thought and only brings this form to a final conclusion and clarity. Physical thought strives to determine and to express in pure objectivity merely the natural object, but thereby expresses itself, its own law and its own principle" (SR 445).

Thereby relativity confirmed the value of Kantian insights, and in particular of Cassirer's original elaboration of neo-Kantianism in *Substance and Function* (1910), where he had argued that scientific thought in its historical development tends to reject the very idea – suggested by the intuitive representation of objects – that truth is correspondence of theories with the properties of a substance and leads towards a conception of knowledge as a functional "coordination" of phenomena according to laws. In this sense relativity was the "triumph of the critical concept of function over the *naive* representation of the thing and the substance" (ECW 10, 65, SR 405).[7]

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[6] Harman 1982, 72-119, 149-155. Cf. Jammer 1997, 136-153.

[7] I quote the English translation in Cassirer 1923.

In particular, special relativity showed the dependence of the form (*Gestalt*) of bodies from the reference system and thus it ruled out the similarity between “optical pictures” and “absolute form [*Form*] of the object” (ECW 10, 50). General relativity eventually disposed of the substantialist meaning of mass. The geometrical interpretation of mass destroyed the foundations of the two main hypostatical concepts of classical physics, atom and ether. First, the new theory of gravitation removed the “dualism” of space and matter that characterized atomism from the Antiquity to Newton (ECW 10, 53-57). Second, the principle of equivalence of inertial and gravitational mass removed the separation of matter and force of Newtonian mechanics, that had formed the basis of a dynamics that could not deduce mass and the laws of motion from the same principle. Finally, the unification of the laws of the conservation of mass and energy, general relativity realized the epistemological objective that 18th century energetics had postulated but – since it considered inertial mass as an independent variable – only realized in a “logically unsatisfactory” way (ECW 10, 10, 57-63). In general relativity the intuitive representation of matter was finally abandoned, as was confirmed by the fact that the new expression of the line element by means of Gaussian coordinates did not include any reference to the “fixed and rigid reference body”. Here was expressed again “the characteristic procedure of the general theory of relativity; while it destroys the *thing-form* [*Dingform*] of the finite and rigid reference body it would thereby only press toward to a higher form of object, to the *true systematic form* [*Systemform*] of nature and its laws» (ECW 10, 62).

Thus general relativity represented a new step in the process of “objectification”, since “by the nature of physical thought, all its knowledge of objects con consist in nothing save knowledge of objective relations”. In other words, relativity confirmed the structural and relational view of scientific knowledge that had been recently advocated by prominent mathematicians and physicists, e.g. Poincaré and Russell, but whose philosophical formulation was already made in Kant’s transcendental logic. Cassirer found support for the latter claim in a passage from the *Critique of Pure Reason*: “whatever we can cognize only in matter is pure relations (that which we call their inner determinations is only comparatively internal); but there are among these some self-sufficient and persistent ones, through which a determinate object is given to us” (Kant 1900–, III, 229. Cf. ivi, III, B 66-67). Thus Cassirer subtly detected a Kantian root of contemporary structuralism, which, in turn, was confirmed by general relativity, for the latter had “shifted these ‘independent and permanent’ relations to another place by breaking up [*in* *dem sie* (...) *auflöste*] with both the concept of matter of classical mechanics and the ether of electrodynamics" (ECW 10, 41–2).

This progressive narrative culminated in the transformation of matter into field. Cassirer presented Einstein's results as the new step of a "progressive transformation of the concept of matter" in "field physics", initiated by early attempts at reducing mass to the electromagnetic field, from Michael Faraday to Gustav Mie and Walter Kauffman (ECW 10, 55–57). This transformation was conceived in the framework of Cassirer's view of scientific progress, according to which successive theories include and expand the relations among phenomena that are introduced in former theories. Cassirer had elaborated this view of scientific progress in *Substance and Function* (1910).

This Neo-Kantian interpretation, I submit, reflected Einstein's original insights only to a limited extent, and was substantially dependent on different scientific sources. To be sure, Einstein was familiar with Kant's philosophy since his youth and he was aware of the rising Neo-Kantianism. Einstein notably attended August Stadler's lectures on Kant and on Theory of Scientific Thought" at the Swiss Federal Polytechnic Institute in Zürich in 1897. Stadler was Hermann Cohen's Phd student and he published a book, *Kants Theore de Materie* (1883) where he examined Kant's dynamical theory of matter in the 1786 *Metaphysical Foundations of Natural Science*.[8] In turn, the new "pure physics" that Kant wanted to establish in this book and recommended mathematical physicists to include in their treatises included a rejection of Newton's position of hard particles as primitive notions: mechanical properties of matter (such as mass) were based on the action of fundamental attractive and repulsive forces of matter. Kant's dynamical theory of matter was a standard element of the Marburg Neo-Kantian narrative of the transition from perceptual to purely ideal representations of matter, and was also mentioned in Cassirer's book of relativity. Now, since Einstein was aware of these precedents and he also read Cassirer's book, scholars have wondered whether he was influenced by Kantianism. Indeed, Einstein he shared some broadly Kantian claims. Einstein's partial appropriation of Kant was not exceptional in the early 20th century, as varieties of Kantianism abounded. Einstein himself, in the famous 1922 discussion of relativity theory in

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[8] For an overview of Einstein's epistemological views and the scholarly debate on this subject see Howard, Giovannelli (2019). Also see Giovanelli (2003) for an analysis of Stadler's works. I thank an anonymous reviewer for pressing me to include Stadler in my story. See below § 4 for Cohen's account of Kant's dynamical theory of matter

Paris, provokingly declared that "every philosopher has its own Kant" (Einstein 1922, 20).[9] In the controversy over quantum mechanics he starkly rejected the "positivistic attitude" (of Bohr, Heisenberg and others) that restricted possible knowledge to the observable and, in this context, he highlighted the valuable Kantian insight concerning the importance of concepts for the definition of physical objectivity.

> "The objective factor [in sense impressions] is the totality of such concepts and conceptual relations as are thought of as independent of experience, viz., of perceptions. So long as we move within the thus programmatically fixed sphere of thought we are thinking physically. Insofar as physical thinking justifies itself (…) by its ability to grasp experiences intellectually, we regard it as 'knowledge of the real' […] The theoretical attitude here advocated is distinct from that of Kant only by the fact that we do not conceive of the 'categories' as unalterable (conditioned by the nature of the understanding) but as (in the logical sense) free conventions. They appear to be *a priori* only insofar as thinking without the positing of categories and of concepts in general would be impossible as is breathing in a vacuum" (Schilpp 1949, 674).[10]

Einstein was also aware of the historically conditioned value of relativity. He maintained that relativistic mechanics did not entirely dismiss Newtonian mechanics, but rather included the latter as a limit case, commenting that "no fairer destiny could be allotted to any physical theory, than that it should of itself point out the way to the introduction of a more comprehensive theory, in which it lives on as a limiting case" (Einstein 1917/1920, 91–92). Cassirer promptly mentioned this thesis, which sounded as a confirmation of his view of the continuity of scientific theories (ECW 10, 17–18, 33). But Einstein was also aware of the open status of his program of field theory of matter. Indeed, Einstein might have considered relativity itself as a step in the progressive series of scientific theories that would be included in a comprehensive field theory. Be that as it may, the construction of that "larger theory" was still in the making. In hindsight, we can see that Cassirer's interpretation went beyond what Einstein himself had established.

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[9] As it has been argued by Massimo Ferrari in an insightful essay, the same might be said of every German physicist between the end of the 19th century and the early 20th century (Ferrari 2006, 183).

[10] Also see Einstein's replies to the essays by Hans Reichenbach and Henry Margenau, ivi pp. 676-679. Reichenbach's theory of a "relativized a priori" in *The Theory of Relativity and A Priori Knowledge* (1921) might have corroborated Einstein's views.

Cassirer indeed found substantial support for his view of field theory in the interpretation of relativity developed by Hermann Weyl. Weyl's *Space Time Matter* (1918) is a major reference in Cassirer's book on relativity, especially when he commented on the "new physical view" of general relativity, as a theory that "no longer recognizes space, force and matter as physical objects separated from each other [since] for it exists only the unity of certain functional relations, which are differently designated according to the system of reference in which we express them". In this context, Cassirer cited Weyl's striking statement that "all physical phenomena are expressions of the world metrics" (SR 398). In fact, Weyl presented the equation of energy and mass in general relativity as a realization of a "pure dynamical view of matter" According to Weyl, "the theory of fields has to explain why the field is granular in structure and why these energy-knots preserve themselves permanently from energy and momentum in their passage to and fro […] therein lies the problem of matter" (Weyl 1952, 208). In other words, the theory of fields had to explain "atoms and electrons" as knots in a field. The solution to this problem lied in the energy tensor of general relativity, resulting in the conclusion that "it is not the field that requires matter as its carrier in order to be able to exist itself, but *matter* is, on the contrary, an offspring of the field". Hence, "in the future we shall assign the term matter to that real thing, which is represented by the energy-momentum-tensor" (ibid.).

Weyl also sketched a progressive narrative of the history of the problem of matter that included most of the references of Cassirer's own narrative. He compared his conclusion to Kant's dynamical theory of matter in the *Metaphysical Foundations of Natural Science* of 1786, citing Kant's "doctrine that matter fills space not by its mere existence but in virtue of the repulsive forces of all its parts" (Weyl 1952, 202 n.). This was of course an important precedent for neo-Kantian accounts of the problem as well (see below § 4). Weyl also pointed out how the electromagnetic field was originally contrasted to "matter" and drew a line from Faraday and Maxwell to general relativity and his own metrical theory of electromagnetism and gravitation, presenting the latter as a transcendental idealistic theory of space and time (Weyl 1952, 2–3).[11] Here we easily recognize the pattern of Cassirer's account of relativistic physics.

However, Weyl himself had not completed his program. In a passage that Cassirer did not mention, Weyl recognized that his metrical theory of electromagnetic and gravitational field

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[11] Weyl's main philosophical model was Husserl's phenomenology, but was certainly familiar with neo-Kantianism. On Weyl's field theory and their philosophical background see Ryckman (2005, 77–94) and Scholz (2006).

was still “lying in the deepest obscurity” (Weyl 1952, 311). Moreover, Weyl changed his theory considerably after the first edition of *Space Time Matter* in order to address criticism of his first formulation of the theory, and eventually he developed a different field theory, connecting quantum mechanical indeterminism with the possibility of a causality grounded on a reality existing beyond the spacetime manifold. On this theory, matter was no longer “dissolved” into the metrical field. Nevertheless, Cassirer did not address these important changes and kept referring indiscriminately to Weyl’s “field theory” as a proof that matter is reduced to field.

In the third volume of the *Philosophy of Symbolic Forms* – the *Phenomenology of Knowledge* (1929) – Cassirer reprised his reference to Weyl’s early program. He maintained that a full “dissolution” of matter could be found in the post-relativistic “theory of field”. Therefore he celebrated the epistemological meaning of the “transition from the physics of matter to the pure ‘field physics’”, as the latter entailed the transition from the intuitive, “geometrical” schematism of classical mechanic to the “universal schematism of the concept of number”, where physical objectivity was defined without any reference to the “world of intuition in its primitive form”, for the field was indisputably an abstract, mathematical concept, with no connection whatsoever to sensory perception. This kind of view, again, had not been developed by Einstein himself, but rather by early interpreters of relativity, such as Weyl in *Space Time Matter* and in the *Philosophy of Mathematics and Natural Science* (1927), Alfred North Whitehead in *An Enquiry Concerning the Principles of Natural Knowledge* (1919), Arthur Eddington in *Space, Time and Gravitation* (1920) (see ECW 13, 507, 524–525, 540–541, 547–549).[12] In particular, Cassirer echoed Weyl’s presentation of matter as a “product of the field”, as Weyl wrote that “what we define as the ultimate physical reality has lost his character of thing: it makes no sense to talk about the same matter in different times” (Weyl 1952, 202–203. See below § 5).[13]

Nevertheless, all these statements concerning the meaning of “pure field physics” belonged to a moment of physical and philosophical research that did not lead to ultimately solid results. Thus Cassirer defended an overoptimistic and slightly generic picture of “field physics”, which significantly characterized the interpretation of relativity. His interpretation of contemporary

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[12] On the notion of “schematism” and its three stages – perceptive, intuitive or geometrical and numerical, see the account in the manuscript *Ziele und Wege der Wirklichkeitserkenntnis* (1937), in Cassirer (1995–2021), vol. 2.
[13] On Eddington, who also maintained that modern physics had given a “death blow to the […] materialistic conception of the ether”, see Ryckman 2004, 108–234.

physics was probably influenced and certainly corroborated by the occasional dogmatic statements of his sources. But Cassirer was a subtle scholar and hardly missed the passages that disconfirmed his convictions; hence we must search for a different explanation of his interpretation. As a matter of fact, the program of a unified field confirmed a postulate on the history of science that Cassirer had formulated since his first works, before the rise of relativity.

## 3. Cassirer's historical epistemology and the problem of matter

In the book on Leibniz, Cassirer already pointed out that the law of continuity entailed the reduction of the material substance to the law of forces and the rejection of the "crass sensory picture" of Cartesian substance, which resulted from the weakness of our sensory intuition. To be sure, as Cassirer was aware that mathematical physics from Galileo to Newton still admitted the existence of independent massive particles. Indeed, he admitted that a full scientific instantiation of these Leibnizian theses could only be found in 19th century physics (ECW 1, 254–71).

However, as we have seen, Cassirer admitted that even the concept of energy did not entirely rule out the hypostatical notions that he wanted to see excluded from natural science, hence this result was not realized until "field physics". Here we find an aspect of Cassirer's argument that needs to be clarified. When Cassirer maintained that a single doctrine realized the ideal of the "dissolution" of matter, and at the same time recognized that this realization was not complete and was rather contradicted by some element of that very doctrine, he was not contradicting himself. His point was rather that the "critical" perspective of the historian allowed to separate the hypostatical and functional trends in a single historical doctrine. At the same time, when he presented a detailed account of crucial notions of modern physics in *Substance and Function*, Cassirer claimed that the history of physics turned out to follow an epistemological direction: "matter itself becomes an idea, for it is more and more clearly reduced to the ideal conceptions that are produced and confirmed by mathematics" (ECW 6, 184. Cf. 206). This means that the original notion of matter as a "substance" that is identified with a particular sensory element, which was typical of Aristotelian physics, is gradually eliminated in the progress of physics (ECW 6, 164), although the hypostatical tendency keeps manifesting itself in modern theories, e.g. in the notion of electric fluids and caloric (ECW 6, 166-167). Indeed, the very concept of the atom was often the object of hypostatical thinking, for it is "the analogue and, as it were, the reduced model of the empirical sensory body" (ECW 6, 218). In fact, the sensory and the intellectual notion of the atom were deeply intertwined from ancient atomism to classical mechanics, although Galileo already formulated the epistemological idea that "the substance of the physical body" is resolved into the properties that arithmetic, geometry and mechanics discover into it (ECW 6, 169, 180–184).[14] Still a full clarification of this idea required the reduction of physical extension to a more abstract principle, as it happened in Roger Boscovich's natural philosophy with centers of forces (ECW 6, 172).

In his account of 19th century atomistic, e.g. in Boltzmann, Cassirer still admitted that the status of matter was controversial, although he identified a constant tendency to abandon the "picture" of the atom (ECW 6, 174). The notion of energy finally entailed an anti-hypostatical principle in itself which provided the ground for the transition from spatial determinations to purely numerical determinations, in that energy unified mechanical, thermal, optical and electromagnetic phenomena by means of a mathematical "principle of coordination", a "pure relation of reciprocal dependency" of variables that identifies the physical object as a structural invariant with no sensory correspondence ( ECW 6, 206, 208–9, 218). But this epistemological interpretation, which was confirmed by the work of scientists such as Robert Mayer, was also historically contradicted by the theorist of "energetics" Wilhelm Ostwald, who defended a hypostatical representation of energy (ECW 6, 150, 151–153; cf. 215).

On the whole, Cassirer characterized the concept of matter (in Kantian terms) as an "intellectual schema", the form of the object in the framework of a peculiar scientific system, rather than a transcendent being. The ultimate determination of matter was a regulative idea which the series of scientific theories approached "more and more" as its "limit structure" (ECW 6, 137-139, 175, 178). In order to connect this epistemological idea with the historical data Cassirer argued, in the "Introduction" of the *Problem of Knowledge*, that

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[14] Galileo, in the third letter to Welser, also admitted that his science only concerned "some accidents [*affezioni*]" afor it was "impossible" to grasp the "true and intrinsic essence of natural substances" (Galilei 1968, V, 187). Cassirer's interpretation had to downplay the importance of such statements.

> “the very concept of history of science contains the idea of the *conservation* of a general logical structure in any succession of particular conceptual systems […] To be sure, also the idea of an *internal continuity* is nothing but a hypothesis, that however – like all purely scientific presuppositions – is at the same time a *necessary condition* of the beginning of historical knowledge (ECW 2, 13, my italics).

Cassirer made clear that the notions of “conservation”, “continuity” and “necessary condition” in this passage should not suggest a picture of the history of science as a linear and uninterrupted progress. “Critical periods” indicated that scientific progress is in fact no mere “continuous quantitative growth”; there is rather a “dialectical contradiction” between different scientific “insights” [*Grundanschauungen*], as “a concept earlier considered as contradictory can later become both a means and a necessary condition of knowledge”, while principles that formerly explained phenomena can be rejected as “absurd and unthinkable” (ECW 2, 4). The characteristic resort to dialectic suggests that Hegelian philosophy was an important model for Cassirer’s project of reconciling theoretical change with the “necessary condition” of continuity in the history of science.[15] Indeed, a certain element of teleological history and Hegelianism was part of the historical epistemology of the Marburg school since Cohen (see below § 4).

Against this background, we can understand better Cassirer’s approach to mass and field in the book on relativity. His account of electromagnetism removed the corpuscular elements in early formulations of the theory (e.g. in Maxwell) and downplayed the open status of the electromagnetic theory of mass.[16] Cassirer found an apparent solution of the problem of matter in Walter Kaufmann’s theory of inertial mass, but then admitted that a further step – relativity – was still required.

> “The inertia of matter […] seems completely replaced by the inertia of energy; the electron – and thus the material atom as a system of electrons – possesses no material but only ‘electromagnetic’ mass. What was previously regarded as the truly fundamental property of matter, as its substantial kernel,

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[15] Cassirer (ECW 12, 33) ultimately endorsed Hegel’s idea of philosophy as a teleological path towards self-consciousness. Kim (2015, 48) also points out an Hegelian side of Marburg historiography.

[16] For historical reconstructions of the electromagnetic theory of mass see Jammer 1997, 136–153. Cf. Harman 1982, 72–119, 149–155, and, for the connection to Einstein, Pais 1982, 172–177.

is resolved into the equations of the electro-magnetic field. The theory of relativity goes further in the same direction" (SR 401)

We recognize here Cassirer's method: he isolates the epistemological intention of a physical theory from its mathematical formulation and empirical confirmation (and possibly also from intention of the theoretical physicists); then he grants that the full theory was still unable to perfectly fulfill the epistemological ideal, and introduces a successive theory that goes a step further in this direction. This suggests that he may have applied the same procedure to relativity: he derived the epistemological meaning of the theory from the consideration of Einstein's equations, popular writings and programmatic declarations; then he might have noticed that Einstein himself wavered as to the proper reduction of mass to the energy of fields, but he considered the interpretations, theories and programs by Weyl, Eddington and other, where he found formulations that matched his own epistemology. This led to his narrative of "field physics".

I will elaborate on the background of this interpretation in the following paragraphs. At this stage, we can already conclude that Cassirer's "structural" interpretation of relativistic physics has to be distinguished by similar attempts. He was not motivated by the need to combine a realism concerning scientific entities and theory change, as many contemporary "structural realists". His objective was also not limited to showing that the Kantian notion of a priori knowledge might be compatible with theory change (as Reichenbach in *The Theory of Relativity and A Priori Knowledge* of 1920). Cassirer was rather motivated by the need to eliminate any residue of intuitive elements (both sensory and geometrical) from the physical notion of matter. This project of a "dissolution of matter", in turn, was not motivated by purely epistemological criteria, such as the inconsistency between continuity of fields and discrete representation of matter that worried Einstein, or by ontological parsimony. It was rooted in a controversy between idealism and materialism that provided one of the signature characteristics of Marburg idealism.

## 4. Platonism in Marburg: "dissolution of matter" and relativity as "the victory of idealism"

As we have seen, Cassirer often refers to a "dissolution" (*Auflösung*) of the concept of matter, meaning a reduction of this notion to mathematical relations, which removes all sensory elements from the representation of objectivity. This idea belonged to the philosophical program sketched by his teacher Hermann Cohen, which entailed an epistemological reappraisal of Platonism across the history of science. This program, in turn, was supported by an interpretation of Plato's theory of ideas as a hypothetical and mathematical method, which provided the background for modern science.[17] According to Cohen, Platonic ideas play an epistemological role mainly as *mathematical* ideas. In fact, sensory perception is merely the "stimulus" for "pure mathematical thought", which investigates the true properties of objects (Cohen 1878, 17–8). Hence existence does not belong properly to sensory objects but only to what is defined by the "methodical connection of thoughts" (ivi, 27).

This interpretation of Plato's theory of ideas followed Cohen' theoretical argument in *Kant's Theory of Experience* (1871), according to which the a priori "does not merely precede objects", but "constructs objects" (HCW, I.3, 49). Cohen's project was to replace the philosophical approaches of sensualism and materialism with the "*epistemologically grounded* idealism" that he derived from Plato (Cohen 1878, 7) and the modern Platonic tradition. Sensualism was unfit to explain the constructive function of logical and mathematical concepts in science. As Cohen would exemplarily write in *The Principles of the Infinitesimal Method* (1883) – paraphrasing Descartes – "stars are not *given* in the sky, but in the reason of astronomy" (HCW 5, 127).[18] Cohen made the same epistemological point regarding materialism, which takes the existence of matter as a primitive fact. Cohen's interpretation of transcendental philosophy was meant as a confutation of this mistaken view (HCW I.3, 270), and can be seen as a late

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[17] On these topics see Pecere 2021. This section and the following are based on this paper

[18] The reference was to Descartes' discussion of our sensory and astronomical ideas of the Sun in the Third Meditation (AT VII, 39).

reaction to the “materialism controversy” that raged in German speaking countries since the 1840s, which opposed the supporters of “scientific materialism” and its critics.[19] On the whole, the interpretations of Plato and Kant resulted in the postulate of a “dissolution” of physical matter into the abstract objective correlate of pure thought. Cohen formulated this doctrine in many statements: “There are no things but in thoughts and on the ground of thoughts” (HCW 5, 126). “Mathematics produces the grounds whereby physics can grasp the nature of being. One cannot start with matter; it is a bastard concept” (HCW 5, 31). To be sure, Cohen was aware that these hypotheses required a justification, but he maintained that to solve the “problem of matter” was the “general problem of philosophy” (HCW 5, 35).

This philosophical problem was at the same time a historiographical problem. Cohen maintained that “only the historical perspective” can reveal the “logical presupposition of science” (HCW 5, iii). This perspective disclosed the connection between Platonism and the idealist epistemology of modern science. For example, “the role of the category of reality for the concepts of matter and nature” had to be derived not from an abstract investigation of the cognitive faculties, but “from those [philosophers], whose works – deeply interconnected with each other – have led to the discovery of modern science. Galileo, Kepler and Newton, Descartes and Leibniz, with their contemporaries and successors, can teach us how to understand Kant and help us to pursue, in his spirit, the labor of philosophy (HCW 5, iv). These natural philosophers were also self-declared followers of Plato and realized a “rejuvenation” of Plato’s theory of ideas (HCW 5, 26). Hence these founders of modern science confirmed Cohen’s thesis concerning the unifying factor in the history of philosophy, which he restated and generalized in later writings: “the history of idealism in general [...] is also the history of Platonic idealism. Philosophy is Platonism” (CW 8, 245).

This approach entailed a constraint on the Marburg Neo-Kantian historiography of science, whose aprioristic tendency – as I have pointed out in regard to Cassirer – was arguably rooted in a Hegelian background.[20] An important example for Cohen was the Neo-Kantian Friedrich

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[19] For an overview of this “materialism controversy” (*Materialismusstreit*) see Bayertz *et al.* (2007) and Beiser (2014), 53–69.

[20] For more details see Pecere 2021, 674–675.

Lange, whose *History of Materialism and Critique of its Present Importance* (1866; 1873-5$^2$) was also meant as a contribution to the materialism controversy in a historico-critical perspective. Lange notably formulated the dialectical argument that a "consequent materialistic view", if only one investigates the foundations of science, "changes round [...] into a consequent idealistic view" (Lange 1866, 496). In his *Introduction* to Lange's *History of Materialism*, Cohen spelled out once more his narrative of progress, presenting the path of scientific research as leading "safely and uninterruptedly to idealism" (HCW 5, 92).

Cohen's idea that matter can be "dissolved" (or "resolved") into forces had a long history in German philosophy, notably in Leibniz's dynamics, which grounded the corporeal substance of Cartesian philosophy in the activity of fundamental forces, and in Kant's "dynamical theory of matter" in the *Metaphysical Foundations of Natural Science* of 1786, which reduces material impenetrability to the action of attractive and repulsive fundamental forces. These doctrines became standard examples of early attempts to solve the problem of matter in the Marburg school, and Cohen exemplarily argued that their epistemological objective would be confirmed with the historical development of science.[21] This kind of dynamism was reprised and developed by Schelling, Hegel, Adolf Trendelenburg and many others. Lange himself argued that the properties of matter can be reduced to the action of forces. He maintained that "the progressive exactitude of research resolves [*auflöst*] matter [*Stoff*] more and more into forces" and that matter is a "misunderstood residue of analysis" (Lange 1875, 204–205).

Other scientific examples discussed by Cohen were Roger Boscovich and Gustav Fechner for their different attempts to combine monads and Newtonian forces in order to explain impenetrability (HCW 5, 135–41). The examination of groundbreaking 19th century physics, from the physics of energy to electromagnetism, was supposed to finally provide a scientific confirmation of Cohen's epistemological hypothesis. Indeed, Cohen argued that Faraday's theory of electricity led to a true "revolution in the conception of matter and, through the transformation of matter into force, to the victory of idealism" (HCW 5, 71). But Cohen

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[21] E.g.: "The materialistic atomism that Leibniz wanted to fight with his monad is rejected by modern mathematical physics" (HCW 5, 134). Cassirer severely criticized Kant's attempt in *Einstein's Theory of Relativity*, where he presents Kant's metaphysics of corporeal science as a mere "philosophical circumlocution" of the presuppositions of Newton's physics (SR 394). This judgement was superficial, for Kant actually took pains to provide an a priori justification of Newton's claims and in some cases replaced them (e.g. with the rejection of absolute space and the demonstration of gravity as essential property of matter. For full reconstructions of Kant's dynamical theory of matter see Pecere 2009; Friedman 2013.

recognized that even Faraday had been just a "forerunner of the new period in natural science" that would only be realized in the electromagnetic theory of mass.

But all these examples, which had been already discussed by Cassirer, were not sufficient to prove the "Platonic" direction of modern physics. Kant's, Boscovich's and Fechner's dynamical theories of matter were not examples of mainstream science. On the contrary, corpuscular theories prevailed in modern physics from Galileo and Newton to the 19th century. The energetic theory of Ostwald was a generalization of conservation laws that did not entail any reduction of mass to differential equations, as required by Cohen's epistemology, and the electromagnetic theory of mass was controversial. Cohen himself conceded that he was postulating a yet unavailable physical theory that would be based on a "more elementary [concept], which could serve as the ground of the definitions of mass, force and energy" (HCW 5, 87). History of science had not realized this objective yet.

Eventually Cohen, in the third edition of the *Introduction* to Lange (1914), saluted Einstein's special relativity as a new achievement in the "history of idealism" because of its abolition of the material ether and the unification of mass and energy. He modified the above quoted passage on the "victory of idealism" (originally referred to Faraday): the victory now consisted in the "transformation of matter into force [and energy]". In spite of his updating of the previous narrative, Cohen added the triumphant declaration: "the path of research leads *with confidence and without deviations* to idealism; at the roots of physical concepts materialism is annihilated" (HCW 5, 91–2, my italics).

Paul Natorp followed Cohen's program by engaging with both the interpretation of Plato and the history of modern science. In *Plato's Theory of Ideas* (1903) he developed in considerable detail Cohen's epistemological interpretation of Plato's theory, but he pointed out that Plato's theory of mass (*onkos*) in the *Timaeus*, although promising in hindsight, was still very undeveloped (Natorp 1903, 375). In *The Logical Foundations of the Exact Sciences* (1910, 381–7), he argued that the "dematerialization of matter" could only be realized in modern physics, e.g. in energetics and electromagnetism. Eventually Natorp did not provide an original and detailed account of the connection of Platonism and contemporary science. This task would be faced by Cassirer, who focused on this problem and eventually produced an ingenious interpretation of relativity as a "Platonic" theory.

## 5. Cassirer, Platonism and relativity

Since his first book Cassirer attempted to provide a corroboration of Cohen's historiographical programme and studied the "Platonic school" that existed throughout modern science (ECW 1, 66), from Galilei and Kepler to Leibniz. Cassirer sharply pointed out that there was no straightforward connection of Platonism and modern science. First, he argued that in Plato's dialogues "the possibility of a rigorous and exact science of becoming is straightforwardly denied" and that, in the physics of the *Timaeus*, "the ultimate explanation of the particular empirical reality is not based on the pure principles of the theory of ideas" (ECW 2, 524). "Only to men of the modern times, only to a Galileo and to a Kepler was possible to be at the same time rigorously Platonic and authentical scientific empiricists" (ECW 2, 527; Cf. 324–325). Second, Cassirer argued that "Platonism" was a sort of ideal standard that modern philosophers and scientists satisfied to different extents. He distinguished different varieties of "Platonism", concluding that Galileo's "physical Platonism" was one that "never [...] had been defended in the history of philosophy and science", for Galileo "accepted Plato's hypothetical method but he gave this method a new ontological status; a status which it had never possessed before" (ECW 24, 337, 351).

Nevertheless, after his work on Einstein's relativity, Cassirer formulated the striking hypothesis that "field physics" was the scientific realization of an idea of matter that could be found in Plato's *Timaeus*. He presented this thesis in his history of ancient Greek philosophy, published in 1925,[22] commenting on the following passage from the *Timaeus* (49d-50c)[23]:

> What we invariably observe becoming different at different times – fire, for instance – to characterize that, i.e., fire, not as 'this', but each time as 'what is such', and speak of water not as 'this', but always as 'what is such'. And never to speak of anything else as 'this', as though it has some stability, of all the things at which we point and use the expressions 'that' and 'this' and so think we are designating something. For it gets away without abiding the charge of 'that' and 'this', or any other expression that indicts them of being stable. It is in fact safest not to refer to it by any of these expressions. Rather, 'what is such' – coming around like what it was, again and again – *that's* the thing to call it in each and every case. So fire– and generally everything that has becoming – it is safest to call 'what is altogether such'. But that *in* which they appear to keep coming into being and *from* which they subsequently pass

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[22] Die Philosophie der Griechen von den Anfängen bis Plato, published in the Lehrbuch der Philosophie, edited by Max Dessoir (Ullstein, Berlin 1925, vol. 1).

[23] Engl. transl. by D.J. Zeyl in Plato (2000).

> out of being, *that's* the only thing to refer to by means of the expressions 'that' and 'this'. A thing that is some 'such' or other, however, – hot or white, say, or any one of the opposites, and all things constituted by these – should be called none of these things [i.e., 'this' or 'that'] […] Now the same account, in fact, holds also for that nature which receives all the bodies. We must always refere to it by the same term, for it does not depart from its own character in any way. Not only does it always receive all things, it has never in any way whatever taken on any characteristic similar to any of the things that enter it. Its nature is to be available for anything to make its impression upon, and it is modified, shaped and reshaped by the things that enter it. These are the things that make it appear different at different times. The things that enter and leave it are imitations of those things that always are, imprinted after their likeness in a marvellous way that is hard to describe.

Here is Cassirer's comment (ECW 16, 448–9):

> The impression of geometrical forms in the homogeneous, in itself undifferentiated substratum of pure space produces the multiplicity that we design, in the language of our sensory perception, with different sensory qualities taken as a multiplicity of empirical substances. This Platonic physics – bodiless, as it were – wherein all being and all material differences are reduced and dissolved into purely ideal geometrical determinations may appear paradoxical, but then it has to be recalled that not only this physics has been not only reprised in principle by Descartes at the beginning of modern philosophy; its fundamental methodical conception also appears to have found a surprising rebirth in the most recent kind of physics, in that general theory of relativity that ultimately reduces all dynamical determinations to pure metrical determinations [here a footnote was appended: "cf. e.g. Weyl, *Space Time Matter*"].

This passage is best understood in the context of contemporary discussions on relativity. The connection of general relativity to Descartes's geometrization of matter was already in Weyl's text, who argued that "Descartes' dream of a purely geometrical physics seems to ne attaining fulfilment in a manner which he could certainly have had no presentiment" (1952, 284). In his 1921 book, Cassirer quoted this passage by Weyl and pointed out the "surprising fact" that "very modern physics […] seems to be again on the road to Descartes, not indeed in content, but certainly in method" (SR 396, 398). In *Philosophy of Mathematics and Natural Science*, Weyl would also propose a similar reading of the *Timaeus*, interpreting both Plato and

Descartes with a substantialist language: “spatial extension is the proper substance of bodies” (Weyl 1949, 179. Cf. *Timaeus*, 48e). Thus Weyl projected the Cartesian *res extensa* back to Platon’s *chôra*. Cassirer’s view – as signaled by his remark on “method” versus “content” – was different, for the mathematization here was taken as a sign of a reduction of sensory objects and pictures to pure relations that was precisely opposed to the “substantialist” talk in science.[24]

In order to make Cassirer’s position stand out in this context, it is important to mention Émile Meyerson’s interpretation of relativity. In *The Relativistic Deduction* (1925), Meyerson also presented a connection between relativity and mathematical Platonism.[25] He pointed out that Weyl had aptly presented the geometrical character of general relativity as “a sort of amalgam of the theories of Newton and Pythagoras […] Since, however, Weyl is stressing here the geometrical nature of this panmathematicism, it would perhaps have been appropriate to add Plato's name to that of Pythagoras, for, as we know, it was he who gave Pythagoreanism a geometrical form” (Meyerson 1925, 152). Meyerson’s epistemological view was that sensations “result from a persistent and unique reality” which lies “*behind* these appearances”. He maintained that this was originally a Platonic teaching.[26] Meyerson also observed that the history of physics appears as “the constant realization of the *Idea,* in the Platonic sense of the term. Despite incessant contradictions inflicted on it by reality, the Idea tends to impose itself upon our conception of reality – to force reality to enter into the mold of the *Same*” (196).

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[24] In *Substance and Function*, Cassirer argued that Descartes’ famous account of the piece of wax in the Second Meditation was insufficient: after reducing the sensory object to extension, the latter had to be “reduced to a pure phenomenon of simple and individual centers of force” (ECW 6, 177–178)

[25] The premises of this connection were already set out in previous works. In *Explanation in the Sciences* (1921), Meyerson connected Plato’s *Timaeus* to Descartes’ geometrical explanation of phenomena (Meyerson 1921/1991, 97–98, 216–218), and in the same context he mentioned Einstein’s relativity as a possible corroboration of Kantian idealism (409).

[26] “Plato already realized this, showing that when different observers conceive differently the size and shape of one and the same thing, it is still possible, by means of number and measurement, to form a unique concept that explains this diversity” (Meyerson 1925/1985, 19). The reference was to *Resp* 602c-603a.

As we have seen Cassirer – who was well-acquainted with Meyerson's work since *Substance and Function* – was not far from the latter's teleological view of history, but he disagreed with Meyerson's search for a Parmenidean "identity" in nature and the conflation of the latter view with the epistemological teaching of Plato. Cohen's and Natorp's researches had shown that Plato, in his late dialogues, had rather started the resolution of sensory things in *relations between multiple forms*. This was the background of Cassirer's interpretation of the Platonic passage as reducing bodies to "purely ideal geometrical determinations".

Cassirer's interpretation and reconsideration of the *Timeus* represents, I submit, the culmination of the historical-theoretical research on Platonism and relativity in the Marburg school. Drawing on the Marburg interpretation of Plato, Cassirer detected an actual Platonic motive in some of the philosophically most prominent scientists and philosophers of his time, like Einstein, Weyl, Eddington, Meyerson and Whitehead. The merits and limits of this interpretation can be best ascertained with the help of a further passage from the *Phenomenology of Knowledge* (ECW 13, 540)[27]:

> "The reality that we designate as a 'field' is no longer a complex of physical things, but an expression for an aggregate of physical relations. When from these relations we single out certain elements, when we consider certain of its positions by themselves, it never means that we can actually separate them in intuition and disclose them as isolated intuitive structures. Each of these elements is conditioned by the whole to which it belongs; in fact it is first defined through this whole. It is no longer possible to separate an individual part, a substantial particle, from the field and follow the movement of these parts for a certain time. Here, then, the method of defining a physical 'object' by a mode of 'indication', a *tode ti*, however subtle, is precluded from the very first. This form of demonstration fails, and must be replaced by a far more complex form of physical deduction. In the ether of modern physics – as Eddington declared on occasion – we can no longer set our finger on a definite place and maintain that this or that one of its parts was in this place a few seconds ago".[28]

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[27] Engl. tr. by R. Manheim (Cassirer 1957, 465).

[28] This expression would also be used by Weyl concerning the identity of the electron (1949, 171).

This quote echoes the above quoted passage from the *Timaeus*: we recognize the critique of sensory perception and the resolution of properties of physical objects into relations belonging to a physico-mathematical whole – the field of contemporary physics –, which realizes the epistemological idea of Plato's *chôra*. Still, Cassirer's subtle interpretation did not solve the problem of Marburg's program. Indeed, as we have seen with respect to Weyl, there was still a gap between Cassirer's epistemological ideal and the historical reality of physics.

## 6. Conclusions

The case study that I have examined shows how the controversy over materialism influenced the Neo-Kantian epistemology of the Marburg school and prepared the interpretation of Einstein's theory or relativity and the program of a unified field theory in the 1920s. The critique of materialism was a driving force in late 19th century and early 20th century German epistemology, which had deep cultural and social motivations besides the purely epistemological side (Köhnke 1991). To be sure, although the connection of anti-materialism and defence of spiritual freedom was still significant in Cassirer and Weyl, their epistemological arguments on matter as a physical concept stood on their own ground and contributed to a lively debate among philosophers and scientists. The limit of Cassirer's perspective (shared with Cohen) was rather the tendency to give for granted the success of an unfinished program for the sake of its epistemological meaning.

Einstein was foreign to the anti-materialist background of Cassirer's views, but he could sympathize with some of their epistemological points. In a letter to Cassirer of 1937, Einstein praised the philosophers's presentation of contemporary physics in *Determinism and Indeterminism in the Modern Physics* (1937). Einstein focused his comment on a passage on Leibniz's rejection of atomism as inconsistent with a "representation according to continuous functions", arguing that this view was "ingenious" and that "in due time" Leibniz would be proved to be "right" (in Cassirer 1996–2021, XVIII, 158–9). This might have sounded like a confirmation of the "Platonic" view of Marburg, which considered Leibniz as the modern champion of idealism and the connecting figure between Plato and Kant, preparing the ground for the "pure field physics". However, Einstein was thinking of the discrete representation of matter in the new quantum mechanics and of his unaccomplished project of replacing this theory with a new system of differential equations. Moreover, Einstein's project of a replacing quantum mechanics was directed by a realist epistemology. He might agree that discrete matter had to "dissolved" into continuous fields "in due time", but was very far from celebrating the "victory of idealism".

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