# History of Physics and the Platonic legacy. A Problem in Marburg Neo-Kantianism*

Paolo Pecere

In this paper I argue that the interpretation of Kant's a priori in Marburg neo-Kantianism involved a historiographical problem concerning the Platonic interpretation of the history of exact sciences. According to Hermann Cohen, the history of modern science supports the philosophical view initiated by Plato and revived by Kant that "the diversity of things has to be dissolved in differences of ideas" and thus points to the "victory of idealism" over empiricism and materialism. I first examine how Cohen and Paul Natorp tried to confirm this epistemological thesis in their historical research on Plato and modern physics. Then I focus on Cassirer's work, which provides the most extensive realization of this historiographical program and, I submit, clearly shows the problematic gap between the "Platonic" epistemology of the Marburg school and the historical reality of physics from Galileo to the early 20th century.

Keywords: Platonism; Cohen; Cassirer; mathematization; matter.

**(1)**

The connection between history of physics and interpretation of Platonism was a characteristic of the Neo-Kantian philosophy of Hermann Cohen and left a crucial legacy in the works of Paul Natorp and Ernst Cassirer. In this paper I want to examine this legacy and point out its problematic character, which has not been the object of targeted reconstructions. Let me briefly outline the problem. The Marburg philosophers maintained that Plato and the Platonic tradition were the source of a major trend in

* [*] I thank two anonymous reviewers for the insightful comments on earlier versions of this paper. I also thank prof. Riccardo Chiaradonna for the instructive conversations on these topics over the last years.

modern physics, resulting in the reduction of material objects to pure mathematical forms and relations. However, modern physics did not meet this "Platonic" standard set by the Marburg philosophers. This historical discrepancy, I will argue, produced a problem for the Neo-Kantian idealism, which depended on this historiographical justification rather than on pure a priori arguments. I will first reconstruct the formulation and defense of the epistemological interpretation of Plato and its historical legacy in the works of Cohen and Natorp. I will then focus on Cassirer, who attempted to realize this program by a more detailed reconstruction of the different stages of modern physics. Cassirer, in particular, established a subtle connection between Platonism and contemporary physics (general relativity and field physics). Nevertheless, I submit, the discrepancy between epistemological ideal and history of science can be found again in Cassirer's work, which therefore did not manage to solve the problem of Cohen's intertwining of historiography and idealism.

## (2) Cohen: Plato, Kant and historical epistemology

Let me first introduce the connection between Platonism and historical epistemology as it is established in Cohen's writings. In *Platons Ideenlehre und die Mathematik* (1878, 1), Cohen claims that "Plato's doctrine of ideas posed for the first time in the history of thought the problem of knowledge. […] With it also begins idealism". Cohen's words carry a Kantian meaning: 'the problem of knowledge' was the question of the latter's validity; 'idealism' was the investigation of the logical and mathematical conditions of possibility of things. In this perspective, Cohen takes Plato's theory of recollection as the "the birthplace of the a priori" (11), that is, as the first philosophical investigation of the necessary presuppositions of knowledge.

On this Kantian interpretation of Plato, ideas[1] had to be conceived in an epistemic rather than an ontological way. Cohen had already hinted at this kind of interpretation in the essay "Die platonische Ideenlehre, psychologisch entwickelt", where he argues that the idea should be conceived as a "regulative concept" of cognition (ECW 12, 173) rather than as "the being of what is intuited" (139).[2] In *Die platonische Ideenlehre*, Cohen develops this regulative interpretation arguing that "the idea itself is thought of as hypothesis" (Cohen 1878, 26). He refers to the account of the dialectical method of Plato's *Republic*: in this argumentative procedure, hypotheses are meant not "as first principles […] but as stepping stones to take off from, enabling it to reach the unhypothetical first principle of everything" (*Rep.* 511b). They are derived by reflecting on the judgments of the sciences (*Rep.* 533d)[3] – by "assuming what is sought is already found" (Cohen 1878, 26) – and turn out to be necessary conditions of the objects of knowledge. Hypotheses play this 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 (17–8). Hence existence does not belong properly to sensory objects but only to what is defined by the "methodical connection of thoughts" (27).

This interpretation of Plato's theory of ideas followed Cohen' theoretical argument in *Kants Theorie der Erfahrung* (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 alternative philosophical approaches of sensualism and materialism with the "*epistemologically grounded* idealism" that he derived from Plato (Cohen, *Ideenlehre*,

1 Throughout the paper I will use the phrase 'Platonic idea' rather than 'form' in order to facilitate the correspondence with the German words 'Idee' and 'Idealismus'.

2 Cohen elaborated on Kant's interpretation in the "Transcendental Dialectic" (405). He also connected the idea as cognitive activity to Fichtean intuition. Nevertheless, I agree with commentators who connect this early essay to Cohens' later neo-Kantian epistemology. See Lembeck (*Platon*, 43, 54); Beiser (*Hermann Cohen*, 31–3).

3 Translation by G.M.A. Grube and G.D.C. Reeve, in Plato, *Complete Works*.

7). Sensualism was unfit to explain the constructive function of logical and mathematical concepts in science. As Cohen would strikingly write in *Das Prinzip der Infinitesimal-Methode und seine Geschichte* (1883), "stars are not *given* in the sky, but in the reason of astronomy" (HCW 5, 127). 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). For these reasons he rejected all the psychological and (more or less) physiological interpretations of the a priori that had been proposed – among others – by Fries, Bona Meyer (I.1, 123ff), Helmholtz (I.1, 295–310) and Lange (I.3, 207–8).[4] While taking sides with idealism, Cohen also wanted to drop the metaphysical claims of absolute certainty that had been typical of post-Kantian idealism, arguing that knowledge depends on a contingent fact and can always be revised (Edel, "Kantianismus", 75ff). He shared the widespread attitude of the post-1848 "theory of knowledge", which looked for a third way between post-Hegelian idealism and materialism (Köhnke, *Neukantianismus*, 58–105, 151–67). Thus Cohen looked for a new logical justification of the a priori that had to disclose the principles of natural science while at the same time granting their historical revisability. Moreover, one needed not merely to engage with natural science – post-Kantian idealists and materialists had done that too – but to prevent philosophical misunderstandings of natural science. For this enterprise Cohen was inspired by the "critical motive" concerning the tradition that was already to be found in Plato's idealism (Cohen, *Ideenlehre*, 8).

Cohen introduced his connection between Platonism and the new historical epistemology in the Preface to *Das Prinzip der Infinitesimal-Methode* (1883). Here

4 Arguably Cohen downplayed the non-reductive sides of the notion of 'organization of the mind' in both Helmholtz and Lange. See Pecere, "Physiological Kantianism".

Cohen maintains that “only the historical perspective” can reveal the “logical presupposition of science”. (HCW 5, iii). In fact – Cohen argues – Kant himself “was led toward the transcendental method not by the sensualism of Illuminists, but by the study of the founders of modern mathematical science of nature” (iv). Following Kant’s model, Cohen wants to establish a new “critique of knowledge, or of science” as a “scientific form of idealism” (6) that investigates the “principles” of science (9). For example, “the role of the category of reality [*Realität*] for the concepts of matter and nature” will have 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 (iv).

The mentioned interconnection among these key figures of modern natural philosophy was precisely the idealistic legacy of Plato, that would be reframed by Kant in critical philosophy. Thus the tasks of verifying the interpretation of ideas as hypotheses in the Platonic tradition and unraveling the idealistic tendency in modern science coincide. As Cohen would put it in his *Einleitung* to Lange’s *Geschichte* (1896): “To understand the idea as hypothesis thus means to understand it in its *historical* rejuvenation through Galileo and Kepler” (HCW 5, 26. Cf. 58). Cohen’s idealistic interpretation of these founders of modern science and self-declared followers of Plato confirms the general thesis concerning the unifying factor in the history of philosophy that he will restate and generalize in later writings: “the history of idealism in general [...] is also the history of Platonic idealism. Philosophy is Platonism” (HCW 8, 245).

A number of sources may have inspired Cohen's quest for a global understanding of the history of philosophy according to an idea.[5] Hegel's connection of history and systematic philosophy was crucial for his professor in Berlin Adolf Trendelenburg (*Untersuchungen*, 6) and also for the methodology of Hermann Steinthal and Moritz Lazarus, the directors of the "Zeitschrift für Völkerpsychologie und Sprachwissenschaft" where Cohen published his first essays. Lazarus ("Gedanken", 44–45) considered books and writings – including scientific works – as vehicles of the "embodiment of thinking", "supports" for the "enduring expression" of the "objective spirit" that, in turn, serves as a collective "content, norm and instrument for men's subjective activities". Cohen would echo these words arguing that transcendental philosophy does not concern a fixed set of "elements" of human cognition, but rather "the supreme principles of an experience that has obtained objective reality in printed books" – i.e. in philosophical-scientific works (HCW 2, 35).

Now, Hegel's objective spirit in its different stages belonged to a teleological philosophy of history that was grounded on the truth of the science of logic. Lazarus, to be sure, protested against this metaphysical dimension of the objective spirit (Beiser, *Cohen*, 27–28) and Cohen, as we have seen, followed this criticism. However, Cohen's philosophical project *does* project a schema of development in the historical succession of scientific works, if only methodologically. A linear view of scientific progress that often had Hegelian undertones was indeed common in contemporary histories of science (Engelhardt, *Historisches Bewusstsein*, in part. 166). A notable case for Cohen was the Neo-Kantian Friedrich Lange, with his dialectical thesis that a "consequent

---

5 Edgar ("Function of History", 2019) investigates the sources of Cohen's historical methodology and argues that the teleological tendency in Cohen's epistemology is introduced with the concept of the 'thing in itself' as an ideal objective of knowledge. I maintain that the model of Platonism was crucial for projecting this ideal in historical perspective.

materialistic view", if only one investigates the foundations of science, "changes round [...] into a consequent idealistic view" (*Geschichte*, 496). In his *Einleitung* to Lange, Cohen would spell out once more his narrative of progress, presenting the path of scientific research as leading "safely and uninterruptedly to idealism" (HCW 5, 92). This would become a problematic burden of Cohen's legacy in Marburg.

## (3) Defending the Plato interpretation: Cohen to Natorp

Cohen's methodological view of Platonic ideas was controversial among scholars (Laks, "Avant Natorp", 158). When Eduard Zeller criticized Cohen's "ahistorical" interpretation, the latter reacted by arguing that "it is in no way a leap from Plato to Kant, when Kant explains his *a priori* by saying that we only know that in the things *a priori* which we ourselves put into them. If he says elsewhere: that which is *a priori* lies at the foundation [*Grund*], here he says: We ourselves put it at the foundation. And in Greek that means: we make the hypothesis" (HCW 5, 27).[6] But this identification of Platonic hypothesis and Kant's transcendental ground confirms how vulnerable and in need of more support was Cohen's transition from Plato to Kant. Cohen's notion of an a priori that included the revisability of the modern scientific hypothesis went far beyond what Plato's texts could support. Kant's separation of a priori concepts and intuitions was also at odds with Cohen's project of unraveling "the secret of idealism", according to which "the diversity of things has to be dissolved in differences of ideas" (HCW I.3, 270) – the "method of purity" that he found theorized in Plato and realized in modern physics. Briefly: Cohen's a priori was neither Kantian (as historical and logically constructive), nor Platonic (as historical and transcendental) (Lembeck, *Platon*, 96–7). Cohen thus left two interconnected tasks to his students: first, to work through his Plato interpretation by means of a more detailed commentary of the texts; second, to justify

6 Engl. tr. by Lydia Patton in Luft (2014).

his thesis of the Platonic and idealist direction of the history of modern physics. The second task required showing that, in the history of physics, the concept of matter is different from the perceptually given object and is more and more "dissolved" into logical and mathematical relations.

Both tasks were pursued by Natorp, whose book *Platos Ideenlehre* (1903, 1921[2]) was significantly subtitled *Eine Einführung in den Idealismus*. Natorp presented Plato's theory as the discovery of the "inner lawfulness by means of which thought itself shapes its object" (Natorp, *Ideenlehre*, 1-2, engl. tr. 53). Ideas are thus "methods and not things: units of thought, pure positings in thought and not external, even if super-sensible, "objects"" (74–5, engl. tr. 108). Besides the theories of reminiscence and dialectic of the *Meno* and the *Republic*, Natorp found additional support for Cohen's views in late dialogues like the *Parmenides,* the *Sophist*, and the *Philebus*. In particular, Plato's theory of the combination of ideas in the *Sophist* (251d ff.) suggested the need to consider ideas as predicates in empirical judgments and thus to conceive of natural becoming. The theory of the *chôra* in the *Timaeus* suggested that the substratum of physical objects was a network of ideal relations, more similar to the space of modern mathematical physics than to Aristotelian matter (Natorp, *Ideenlehre*, 366ff.).[7]

Natorp's interpretation of ideas as epistemological conditions deserved scholarly attention and is still considered by historians.[8] However, Natorp's attempt at reducing Platonic ideas to *laws* of modern science is too hasty, e.g. when Natorp (410) presents Newton's law of gravitation as a kind of Platonic idea. Natorp admits that Plato had not realized the physics that he anticipated (375). To be sure, according to Natorp, Plato's

---

7 Cf. *Parmenides* (26 a-d), *Philebus* (24d; 26d), *Politicus* (269d-e; 237b-d). Cohen (HCW 5, 29) already suggested this reading.

8 Lembeck 1994, pp. 194–250, Gigliotti (2005, 2010), Kim (2010). For a critical view of this tradition see Trabattoni (2012).

conception of matter – in the *Philebus* – as an undetermined ‘x’ that is the subject of an infinite process of mathematical determination would eventually prevail over the “dogmatism” of Aristotle’s “concrete and sensible individual substance” (398, Engl. tr. 351). But this would only gradually emerge from the historical path of science:

“science undermines at every point this false confidence about thing-like subjects. For science it becomes ever more evident that precisely this ultimate and distinctly conceived subject of change – be it matter, or material elements, or atoms, or mass points, or whatever else they may be called – amounts to mere attempts and not ultimate foundations, mere endeavours and not definitive determinations.” (406, engl. tr. 357).

Natorp had already summarized this thesis in his essay on Galileo with a formula: “the idea” is “the root of all true science” (Natorp 1883). By emphasizing the historically normative value of epistemological ‘Platonism’, Natorp touched upon a new problem: if Aristotle’s correspondence theory of truth had to be replaced in the light of the historical process of scientific determination, then a new criterion of truth was needed in order to avoid historical relativism. This problem would be detected and addressed by Cassirer.

## (4) Enter Cassirer: “physical Platonism” and the invariants of history

In the first decade of the 20th century Cassirer, from *Leibniz’ System* (1902) to *Das Erkenntnisproblem* (1906–7) and *Substanzbegriff und Funktionsbegriff* (1910), attempted to provide a corroboration of Cohen’s historiographical program, focused on the Platonism of modern philosophy and science.[9] Cassirer clearly spelled out that his historiographical program and the revival of critical idealism were joint enterprises, for the task of an investigation based on the transcendental method was the “continually

---

9 Cohen himself referred to Cassirer’s work in the third edition (1914) of his *Einleitung* to Lange (HCW 5, 26). Translations of Cassirer’s works are mine, unless otherwise specified.

renewed examination of the fundamental concepts of science, [...] which simultaneously involves a thorough subjective self-examination of the critique itself" (ECW 9, 37).

In *Leibniz' System*, Cassirer summarizes the program and acknowledges that a "Platonic school" existed throughout modern science and in particular astronomy (ECW 1, 66). Kepler's concept of *vera hypothesis* gave a mathematical development to Plato's objective of "saving the phenomena" and established "the foundations of the modern concept of natural law" (321–22).[10]

Cassirer clarified that this notion of Platonism was a sort of ideal standard that "Platonic" modern philosophers satisfy to different extents. For example, here is how he compares Descartes' explanation of gravity through "concrete material agents" (particles) – which would adhere too much to sensory intuition – to Galileo's purely mathematical interpretation:

> "Galilei thinks in a *more idealistic and more Platonic way* than Descartes, for he is guided by the awareness that the mind is blind if it pretends to see immediately what exists, and that the *alêtheia tôn ontôn* can only be known through the *logoi*" (ECW 1, 68, my italics).[11]

The modern philosopher who first grasped "the most profound logical scientific meaning of the idea […] as hypothesis" was Leibniz. Leibniz' philosophy was thus the "ideal mediation between Plato and Kant" (110–1) because it connected the idea with the definition and thereby with the law of the states that characterizes the substance. Moreover, Leibniz' law of continuity introduced the mathematical analysis of geometrical forms and motion, and this analysis, in turn, could be taken as an application of the Platonic principles of *koinônia tôn genôn* and *kinêsis* of ideas in the

10 On Plato's view of astronomy Cassirer quoted Simplicius' *Scholia* to *De caelo*, II, 12.
11 The reference was to *Phaedo,* 99d.

*Sophist*, for qualities and quantities resulted from the combination of multiple abstract factors (ECW 1, 198–201. Cf. *Soph*. 249b-c). On the physical side, 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. Nevertheless, a full scientific instantiation of these Leibnizian theses could be found only in 19th century physics (ECW 1, 254–71).

So far Cassirer was following in the footsteps of Cohen and Natorp. A more original trait of his research was the subtler understanding of the category of "Platonism" in its historiographical and epistemological aspects. In the Preface and the Introduction to the *Erkenntnisproblem* (1906), Cassirer once more presents the rejection of the correspondence theory of truth and the view of scientific concepts as "creations of thought" as part of the Platonic legacy. The adoption of this perspective requires a postulate on the history of science.

> 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 makes clear that his use of 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" indicate 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 formely explained phenomena can be rejected as "absurd and unthinkable" (ECW 2, 4). The characteristic resort to dialectic, here and elsewhere in the *Erkenntnisproblem*, 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.[12] But this does not mean that Cassirer wanted to merely postulate a teleological rationality of history in Hegelian sense. His characterization of historical continuity as a "hypothesis" suggests that he was rather inspired by the interpretation of *Plato's* dialectic as a hypothetical method guided by a regulative idea, which – as we have seen above – was a distinctive mark of Marburg Neo-Kantianism. This model was particularly useful in order to analyze theoretical conflicts in science and to find their solution in a successive and more comprehensive theory, which was a characteristic feature of Cassirer's historiographical method.

The legacy of Platonism also provided a key to securing that these conflicts did not break the continuity in the history of science, albeit this thesis, in Cassirer's works, raised the need of a more detailed and complex historical justification than those given by Cohen and Natorp. In § II of the Introduction to the *Erkenntnisproblem*, Cassirer elaborates on his necessary hypothesis of structural "conservation" and historical "continuity", looking for its unifying element in the idealistic and Platonic tradition. He points out – more sharply than Natorp – that the promising elaborations of the late Plato did not eliminate "the old dualistic contrast between the domain of being and the domain of becoming" and that in the *Philebus* "the possibility of a rigorous and exact science of becoming is straightforwardly denied" (cf. *Phileb*. 59a-b). These limits also belong to the physics of the *Timaeus*:

12 On the importance of Hegel's philosophy of history for Cassirer see the Conclusions below.

> One can certainly ascribe to the myth much of the elaboration on empirical physics of the *Timaeus* […] however, as a matter of fact, the ultimate explanation of the particular empirical reality is not based on the pure principles of the theory of ideas, and this fact requires a theoretical and historical justification (ECW 2, 524).

This justification is that the science of Plato's time was not adequate for the "rigorous ideal of knowledge, that he advances and that the modern development attests and confirms". This weakness appeared in ancient astronomy in particular, which did not possess an arithmetical account of celestial motions and therefore was criticized by Plato (ECW 2, 525. Cf. *Resp*. 529d ff.). The limit of arithmetic methods of the Pythagorean tradition was evident in the *Philebus*, where Plato "has only a few effective examples from acoustics at his disposal". Hence, "It cannot surprise anyone who considers things historically that he did not foresee the degree of resolution and mastery of sense data that can obtain through pure mathematical forms" (ECW 2, 526–7). Nonetheless Plato anticipated the "meaning and task" of an empirical and mathematical science that was eventually realized in modern times:

> 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; only to them experience was not an obstacle to overcome anymore, but the true fulfillment and conclusion of pure theory (ECW 2, 527).

Galileo followed Plato's "ideal" that true knowledge can only be derived from the necessary principles of mathematics, but he applied this ideal to physical objects (ECW 2, 324–325). Because of this innovation, however, this modern Platonism was radically different from the ancient one and hence the historical ‘continuity’ that Cassirer was searching for seemed only problematically established by its existence.

This could be a reason why Cassirer eliminated the whole § II in the second edition of the *Erkenntnisproblem* (1911). The previous year, in *Substanzbegriff und Funktionsbegriff*, he had published a different account of the problem, arguing that the ‘continuity’ of scientific progress could be established through “invariants of experience”. On this account, the progress depended on the capacity of every successive theory to assimilate and generalize the connections among phenomena that were established by previous theories, rather than on a better correspondence to a given objectivity. The comparison between different scientific systems, in turn, required a set of general concepts of measure, which included space, time, number and functional dependence. While these categories were a constant of scientific investigation, their specific content changed throughout the history of science, but this change followed a rule of convergence that was defined in retrospect from the standpoint of the most effective description of phenomena.[13]

This search for “invariants” depended on the model of 19th century exact sciences[14] and did not seem to require a “Platonic” foundation anymore. In the light of this program Cassirer tried to find a continuity in the succession of leading theories in contemporary physics. However, to take physical theories of the present as the standpoint for this project required an idealistic interpretation of these theories. Indeed, Cassirer contended in different passages that theories of physics in the late 19th and early 20th century presented matter as an “idea”, using a term that could evoke at the same time the original Platonic notion and its Kantian interpretation as “regulative idea”. In this

13 ECW 6, 162, 274, 347–350. On the categories see 334, 348

14 E.g. Felix Klein’s “Erlangen Program” was a model for Cassirer’s epistemology (see Ihmig 1999).

regard, as we will see in more detail in the next section, Cassirer would constantly resort to the guiding thread of Platonism.

As Cassirer reframed his historiographical and epistemological perspective in the "Philosophy of symbolic forms", however, historians were turning away from the neo-Kantian view of Plato because of its unilateral focus on natural science (Hartung 2012, 248-252). In 1933, Gadamer would retrospectively remark that the "dominant approach of Platonic studies is that neither science, nor art, nor mystic are sufficient to provide a conclusive view [of Plato's philosophy]; the point is rather to understand the whole creative activity of Plato through these categories" (Gadamer 1985). In the 1920s, Cassirer faced precisely this challenge by dealing with language, myth, artistic expression and scientific representation as different symbolic forms. He established an analogy between symbolic forms and Platonic ideas, based on the common paradigmatic and constructive function of these notions with respect to the alleged ontological priority of being and external objects of the "realistic worldview" (cf. ECW 11, 2ff). In his "Philosophie der Griechen" (1925), he established a connection between his new project and the philosophical task set by Plato, "to turn the sensible existence into spiritual meaning and thus to imprint the true 'seal of being' (cf. *Phaed* 75d)", a task that Plato had fulfilled as "investigator of scientific method, and as moral, political and religious reformer" (ECW 16, 423). Thus Cassirer refined his historiographical perspective on Platonism in parallel to the development of his new philosophy.

In the 1940s, Cassirer dealt again with the problem of scientific change and took the opportunity to clarify his own view of Platonism in modern physics. In the essay "Mathematical Mystique and Mathematical Science of Nature" (1940), Cassirer restated the problem of scientific change in terms of "revolutions": "rather than dealing with an evolution, we are dealing with an unexpected revolution." (ECW 22, 285). This sounds familiar from the perspective of contemporary history of science, and indeed it has been argued that Cassirer had been dealing with the problem of "paradigm change" in Kuhnian terms.[15] However, Cassirer did not want to admit a radical break in the history of science: "We are never truly dealing with an interruption in the continuity" (ibid.). To be sure, Cassirer did not want to subscribe to a *radical* continuity either, for that would undermine the novelty of the astronomical revolution from Copernicus to Kepler with respect to the past, as it happened in Pierre Duhem's studies (Ferrari 2015, 17–18). Thus Cassirer came back to his old problem of assessing the difference between ancient and modern Platonism. He dealt with it in detail in "Galileo's Platonism" (1946), in response to Koyré's claim that "the new science is for him [Galileo] an experimental proof of Platonism" (Koyré 1943, 428). In his account Koyré took for granted a separation of mathematics from its experimental application, as he did not subscribe to the neo-Kantian view that mathematics had a transcendental function in the representation of the physical object and he was rather influenced by a realist view of both mathematics and physics derived by Edmund Husserl and Émile Meyerson. (Ferrari 2015, 20–27). In his comment, Cassirer first distinguished the skeptical, mystical, mathematical and religious aspects of the Platonic tradition and then pointed out that the alternative between mystical and mathematical Platonism was too restrictive to account for the Platonic legacy in modern science. Cassirer maintained that Galileo developed what was best called a "physical Platonism" and made clear that "never before such a Platonism had been defended in the history of philosophy and science" (ECW 24, 337). To be sure, Galileo "acted as a faithful disciple of Plato" in following the method of hypotheses, but he conceived of mathematics as a condition for the

---

15 Ferrari (2015, 16) points out that Alexandre Koyrè had used the word 'revolution' in his recently appeared *Études galiléennes* (1939) and Cassirer may have been aware of that. On the connection of Cassirer's problem with Kuhn's paradigm change see the insightful account by Friedman (2010b).

knowledge of nature. Hence “he had to deviate both from the principles of Platonism and Aristotelianism. He accepted Plato’s hypothetical method but he gave this method a new *ontological* status; a status which it had never possessed before” (ECW 24, 351).

Thus Cassirer adjusted his historiographical category to the epistemological perspective that he held since the *Erkenntnisproblem*: modern scientific experience depended on mathematics as a spontaneous activity of reason, which organized phenomena according to functional laws and thereby formed objectivity. This result of modern science depended indeed on the legacy of Platonism, as Cohen had maintained, but the path of idealism was far from “uninterrupted” and unproblematic.

## (5) “Dissolution of matter”: from the *Timaeus* to 20th century physics

Cassirer’s joint investigation of history of Platonism and epistemology of modern physics found its most original result and possibly its culmination in the 1920s, with the thesis that post-relativistic “field physics” ultimately produced a “dissolution” of the concept of matter into ideal relations, and in so doing realized an original Platonic insight. In order to understand this thesis, it is necessary to introduce it against the background of Cohen’s and Natorp’s work.

Cohen’s Plato interpretation, as we have seen, involved a reaction to materialism and resulted in the postulate of a “dissolution” of physical matter into the abstract objective correlate of pure thought. As Cohen puts it: “There are no things but in thoughts and on the ground of thoughts” (HCW 5, 126). To solve this “problem of matter” is the “general problem of philosophy” (HCW 5, 35). “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).

Cohen's idea that matter can be "dissolved" (or "resolved") into forces had a long history in German philosophy: starting from Kant's "dynamical theory of matter" in the *Metaphysische Anfangsgründe der Naturwissenschaft* (1786), Hegel, Trendelenburg, Lange and many others argued that the properties of matter have to be reduced to the action of forces. Lange (*Geschichte*[2], II, 204) 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" (205). Cohen's original perspective was that the concept of force itself had to be resolved into pure mathematical laws and stripped of any trace of sensory qualification. The historical confirmation of this view was found in different moments of the history of physics, from Leibniz' 'Platonic' fresh start to the present: "The materialistic atomism that Leibniz wanted to fight with his monad is rejected by modern mathematical physics" (HCW 5, 134). Other examples given in the *Infinitesimal-Methode* are Roger Boscovich and Gustav Fechner, for their different attempts to combine monads and Newtonian forces in order to explain impenetrability (HCW 5, 135–41). In the first edition of the *Einleitung* to Lange (1896), Cohen argued that Faraday's theory of electricity led to a true "revolution [*Umwandlung*] in the conception of matter and, through the transformation of matter into force, to the victory of idealism" (HCW 5, 71). But Cohen recognized that Faraday had been just a "forerunner of the new period in natural science" that would only be realized in the electromagnetic theory of mass. The "victory" of idealism was postponed to the frontier of contemporary research.

One more episode in Cohen's investigation was the debate on the foundations of mechanics between Ludwig Boltzmann, with his atomistic theory, and Wilhelm Ostwald, who wanted to replace particles with the concept of energy (energetics). Cohen examined the controversy and concluded that "in both, a pure, rigorous thought-element is made the foundation of existence, the basis of reality, instead of sensory intuition" (HCW 5, 68). Cohen finds a sympathetic position in Heinrich Hertz' account in the *Prinzipien der Mechanik* (1894). Hertz followed the sign-theory of Helmholtz and argued that the choice between different "pictures" (*Bilder*) of physics depends on logical criteria such as clearness and lack of ambiguity. Cohen particularly liked Hertz's own set of principles, where force is no longer a fundamental variable (Patton, "Cohen", 137ff).

But these references were not homogenous and, on the whole, 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. The electromagnetic theory of mass was a popular but controversial hypothesis at the end of the 19th century. 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 had not realized this objective yet.

Eventually Cohen turned to 20th century physics and, in the third edition of the *Einleitung* to Lange (1914), swiftly 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 integrated the quoted passage on the "victory of idealism", which consisted now in the "transformation of matter into force [and energy]". In spite of his updating and correction, 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).

Natorp examined the same examples in *Die logischen Grundlagen der exakten Wissenschaften* (1910) (Natorp, *Grundlagen*, 381–7), recognizing that the "dematerialization of matter" could only be realized in modern physics, e.g. in energetics and electromagnetism. He pointed out that Plato's theory of mass (*onkos*) in the *Timaeus* was promising in hindsight, but still very undeveloped (Natorp 1903, 375). Again, the connection between modern physics and Platonism was scarcely elaborated.

In *Substanzbegriff*, Cassirer also elaborates on these examples and concludes that in modern physics "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). The concept of matter thus refers (in Kantian terms) to an "intellectual schema", the form of the object in the framework of a peculiar scientific system, rather than to a transcendent being. The ultimate determination of matter is a regulative idea which the series of scientific theories approaches "more and more" as its "limit structure" (ECW 6, 137-139, 175, 178).

In the 1920s, Cassirer expands this view to contemporary physics and epistemology. In his book on Einstein's relativity (1921), Cassirer praises general relativity because it "dissolved [*auflöste*] both the concept of matter of classical mechanics and the concept of ether of electrodynamics" and highlighted the "independent and persistent" mathematical relations which determine objectivity in both theories (ECW 10, 41–2). Einstein's work is presented as the culmination of a "progressive transformation of the concept of matter" in "field physics", initiated by early attempts at reducing mass to the electromagnetic field, from Faraday to Mie" (ECW 10, 55–57). "In this way, the sensuous manifold […] assumes the imprint of thought, the imprint of the systematic unity of form" (59). Cassirer finds support for his view of scientific progress in Einstein's thesis that his theory does not entirely dismiss the previous one (Newtonian mechanics), but rather includes the latter as a limit case (ECW 10, 17–18, 33. Einstein 1917, 52).

On the whole, this picture was arguably simplistic. Cassirer shared the expectations of many scientists about the electromagnetic theory of mass: in *La fin de la matière* (1906) Henri Poincaré had recently reported that according to many physicists "matter does not exist", but he immediately added: "this discovery is not conclusive" (see Poincaré 1908, 282). Cassirer's view of the history of electromagnetism removed the corpuscular elements in early formulations of the theory and downplayed the open status of the electromagnetic theory of mass.[16] As regards relativity (both special and general), Cassirer's conclusion obscured the fact that Einstein had not explained away the concept of mass. Yet Cassirer found support for his view in a similar progressive narrative sketched by Hermann Weyl in *Raum Zeit Materie* (1918), where the electromagnetic field was contrasted to "matter" and a line was drawn from Faraday and Maxwell to general relativity and Weyl's own metrical theory of electromagnetism and gravitation, presented as a transcendental idealistic theory of space and time (Weyl 1952, 2–3).[17]

In the third volume of the *Philosophie der symbolischen Formen* – the *Phänomenologie der Erkenntnis* (1929) – Cassirer reprised this reference to Weyl's early program. He maintained that the full realization of this "dissolution" process had to be found in the post-relativistic "theory of field", for field was indisputably an abstract, mathematical concept, with no connection whatsoever to sensory perception. This theory had been notably developed by Weyl in *Raum Zeit Materie* and in *Philosophie der Mathematik*

16 Harman 1982, 72–119, 149–155. Cf. Jammer 1997, 136–153.
17 On Weyl's field theory see Ryckman (2005, 77–94) and Scholz (2006).

*und Naturwissenschaft* (1927) and by Arthur Eddington in *Space, Time and Gravitation* (1920). Weyl's theory presented matter as a "product of the field" and proved 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" (ECW 13, 541, 548–549. Cf. Weyl 1952, 202–3).[18]

It is no surprise, at this stage of our investigation, that Cassirer presented this thesis, in the *Philosophie der Griechen* (1925), as the modern version of an originally Platonic insight. Cassirer commented on this passage from the *Timaeus* (49d-50c, tr. D.J. Zeyl):

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 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.

---

18 These pages also include references to Eddington, who also maintained that modern physics had given a "death blow to the […] materialistic conception of the ether". On Eddington see Ryckman 2004, 108-234.

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 is 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 nature was already in Weyl's text (1952, 284). In *Philosophie der Mathematik und Naturwissenschaft*, Weyl himself 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 was different, for the mathematization here was taken as a sign of that reduction of sensory objects and pictures to pure relations that was precisely opposed to the "substantialist" talk in science.

One more important reference in this context was Émile Meyerson's interpretation of relativity. In *La déduction relativiste* (1925), Meyerson also presented a connection between relativity and mathematical Platonism.[19] He pointed out that Weyl had aptly presented the geometrical character of general relativity as "a sort of amalgam of the

19 The premises of this connection were already set out in previous works. In *L'explication dans les 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).

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.[20] 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). Cassirer – who was well-acquainted with Meyerson's work since *Substanzbegriff* – was not far from the latter's teleological view of history,[21] 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 modern physics 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

---

20 "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.

21 See below footnote 26.

merits and limits of this interpretation can be best ascertained with the help of a further passage from the *Phänomenologie der Erkenntnis* (ECW 13, 540)[22]:

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.[23]

This passage echoes the above quoted passage on 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 does not solve the problem of Marburg’s program.

Indeed, however ingenious and close to contemporary developments was Cassirer’s view, there was still a gap between its epistemological ideal and the historical reality of physics. Weyl himself, in a passage that Cassirer did not mention, recognized that his metrical theory of electromagnetic and gravitational field was still “lying in the deepest obscurity” (Weyl 1952, 311). Moreover, Weyl changed his theory considerably after the first edition of *Raum Zeit Materie* in order to address criticism of his first formulation of

22 Engl. tr. by R. Manheim (Cassirer 1957, 465).

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

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. However, 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 and material causality is replaced by "form".[24]

Indeed, Einstein himself continued to admit that a theory of a continuous fields as sources of material particles was epistemologically ideal, but he soon lost interest in Weyl's attempt and continued to present this view as a working hypothesis (Pais 1982, 312–313, 345–376, 488–497). In 1937, Einstein wrote to Cassirer to praise the latter's presentation of contemporary physics in *Determinismus und Indeterminismus in der neueren Physik* (1937) and commented that Leibniz' rejection of atomism as inconsistent with a "representation according to continuous functions" was "ingenious" and that "in due time" Leibniz would be proved to be "right" (in Cassirer 2009, XVIII, 158–9). This may have sounded like a confirmation of the "Platonic" view of Marburg, which considered Leibniz as the modern champion of idealism and the connecting point between Plato and Kant. However, Einstein was thinking of the discrete representation of matter in the new quantum mechanics and of his project of replacing this theory with a new system of differential equations, which was an isolated and unaccomplished enterprise. Moreover, Einstein's project of a replacing quantum mechanics was directed by a realist epistemology. He was very far from celebrating the "victory of idealism".

On the whole, Cassirer's view of relativity and field theory, however ingenious, was biased and failed to realize the Marburg program.

Cassirer's investigation of quantum mechanics in the 1930s was similarly biased. In *Determinismus und Indeterminismus*, Cassirer finds a confirmation of his epistemology

24 See, e.g., ECW 24, 455. I thank an anonymous reviewer for pressing me on this point.

in the new theory that – according to Bohr and Heisenberg – "gives up" any intuitive representation of objective reality and reduces the atom to a mathematical "system of relations" (ECW 19, 160, 163). He qualifies quantum mechanics as a "'Pythagorean' theory of nature" (ECW 19, 205), thus focusing on the arithmetic side of mathematical Platonism. Since the late 1920s, indeed, Cassirer pointed out that the arithmetical reduction of perceptual data, or "numerical schematism", was a different and more advanced stage of knowledge than the "geometrical or intuitive schematism" of Galileo and Descartes that he had previously read (with Weyl and Meyerson) in the light of Plato's *Timaeus*.[25] In this perspective, Cassirer particularly endorsed Paul Dirac's formulation of quantum mechanics because its characterization of the "physical state" of a system by a "symbolic algebra of observables" most clearly separated the pure logical meaning of scientific theory from the intuitive representation of matter (Ryckman 2018). However, once more Cassirer neglected the controversial status of quantum mechanics and the alternative realistic theories and interpretations that Schrödinger, de Broglie and others were still defending (see Pecere 2011). The "victory of idealism" could not be celebrated yet.

**Conclusions: Marburg epistemology without "Platonism"?**

In the light of my analysis, Cassirer's view of scientific progress, with its tension between Platonic idealism, epistemology and historical data, can be suspected of the same "quasi-Hegelian" teleology that has appeared as an unwanted consequence of

25 In the 1937 manuscript *Ziele und Wege der Wirklichkeitserkenntis*, Cassirer (2009, II), Cassirer sums up his conceptions with a hierarchy of three "schematisms" of physics: the "perceptual schematism" of Aristotle, the "geometrical or intuitive schematism" of Galileo and Descartes and the "numerical schematism" that finally dissolves matter into laws expressed in a symbolic system, typical of contemporary physics.

Cohen's program.[26] Cassirer correctly diagnosed that physics proceeded towards mathematical concepts that were more and more detached from sensory impressions. On the other hand, he wanted to derive from this epistemological fact the idealistic thesis that material objects are merely abstract correlates of scientific thought. This claim, that Cohen had first derived from the legacy of Plato and directed against realist interpretations of Kant and materialism, was insufficiently corroborated by contemporary physics. The latter, as it were, turned out to be not "Platonic" enough.

This problem might be avoided if we conceive of the a priori notion of scientific objectivity of the Marburg School as a *regulative* rather than a *constitutive* idea, as a "task" or "demand" (ECW 6, 290) that is growingly confirmed in the succession of scientific theories (Friedman 2010, 680ff).[27] This would save Cassirer's valuable historical insights and defend his "logic of objective knowledge" as a non-dogmatic understanding of the unity and progress of physics. Moreover, we could take Platonism as the major historical source for the regulative – or "meta-scientific" – idea of knowledge that guided the transition from one theory to the other.[28] On this interpretation, however, the epistemological interpretation of modern science turns out to be insufficient to confirm the thesis of the "dissolution of matter" and hence to support a refutation of realism and materialism. As soon as these signature objectives of Marburg Neo-Kantianism are taken into consideration, the conflict between 'Platonic' epistemology and history of science resurfaces.

---

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

27 On Friedman's interpretation as an alternative to a Hegelian interpretation see Richardson 2010.

28 On the thesis that philosophies may play this "meta-scientific" and "regulative" role in a post-Kuhnian epistemology see Friedman 2001, 105–115, and Friedman 2010, in part. 716–17 (and n. 324).

## References

Beiser, Frederick C. *Hermann Cohen. An Intellectual Biography*. Oxford: Oxford University Press, 2019.

Cassirer, Ernst. *The Philosophy of Symbolic Forms. Vol. 3. The Phenomenology of Knowledge*. New Haven/London: Yale University Press, 1957.

Cassirer, Ernst. *Gesammelte Werke*, hrsg. von B. Recki. Hamburg: Meiner, 1998–2009 (=ECW).

Cassirer, Ernst. *Nachgelassene Manuskripte und Texte*. Hamburg: Meiner, 2009.

Cohen, Hermann. *Platons Ideenlehre und die Mathematik*. Marburg: Pfeil, 1878.

Cohen, Hermann. *Werke*, ed. Hermann-Cohen-Archiv unter Leitung von Helmut Holzhey. Hildesheim: Olms, 1987–2002. 17 vols [= CW].

Edel, Geert. "Kantianismus oder Platonismus? Hypothesis als Grundbegriff der Philosophie Cohens". *Il cannocchiale*, 1-2 (1991): 59–87.

Edgar, Scott. "The Function of History in Cohen's Critique of Knowledge". Unpublished draft (2019).

Einstein, Albert. *Über die spezielle und die allgemeine Relativitätstheorie (Gemeinverständlich)*. Vieweg: Braunschweig, 1917[2.]

von Engelhardt, Dietrich. *Historisches Bewusstsein in der Naturwissenschaft von der Aufklärung bis zum Positivismus*. Freiburg-München: Alber, 1979.

Ferrari, Massimo. "Ernst Cassirer and the History of Science". In: J. Tyler Friedman, Sebastian Luft (eds.), *The Philosophy of Ernst Cassirer. A Novel Assessment*. Berlin/Boston: De Gruyter, 11–29.

Friedman, Michael. *Dynamics of Reason*. Chicago: Open Court, 2010.

Friedman, Michael. "Synthetic History Reconsidered". In: Mary Domski, Michael Dickson (eds.), *Discourse on a New Method*. Chicago-La Salle: Open Court, 2010, 571–813.

Friedman, Michael. "Ernst Cassirer and Thomas Kuhn: The Neo-Kantian Tradition in the History and Philosophy of Science". In: R. A. Makkreel, S. Luft (eds.), *Neo-Kantianism and Contemporary Philosophy*, Bloomington and Indianapolis: Indiana University Press, 2010[b], 177–191.

Gadamer, Hans-Georg. "Die neue Platoforschung". In: *Gesammelte Werke*, Bd. 5, Tübingen: Mohr Siebek, 1985, 212–229.

Gigliotti, Gianna. "Natorp tra Platone e Kant", *Rivista di Storia della Filosofia*, 3 (2005), 443–71.

Gigliotti, Gianna (2010). *La Passion de la science rigoureuse. "Trieb und Methode": Natorp lecteur du* Phèdre". In A. Brancacci, D. El Murr, D. P. Taormina (éds.), *Aglaïa. Autour de Platon*. Paris: Vrin 2010, 521–44.

Hartung, Gerald (2012). "Logos und Mythos in der Philosophie Platons: Ernst Cassirers Platon-Bild". In M. Erler, A. Neschke-Hentschke (Hrsg.), *Argumenta in dialogos Platonis*, Teil 2: *Platoninterpretation und ihre Hermeneutik von 19. bis zum 21. Jahrhunderts*. Schwabe: Basel, 247–63.

Ihmig, Karol-Nobert (1999). "Ernst Cassirer and the Structural Conception of Objects in Modern Science: The Importance of the 'Erlanger Programm'". Science in Context, 12(4), 513–529.

Jammer, Max (1997) *Concepts of Mass in Classical and Modern Physics*, Dover: Mineola (N.Y.).

Kim, Alan. *Platon in Germany: Kant – Natorp – Heidegger*. Sankt Augustin: Academia Verlag, 2010.

Kim, Alan (2015). *Neo-Kantian ideas of history*. In N. De Warren & A. Staiti (eds.), *New Approaches to Neo-Kantianism*. Cambridge: Cambridge University Press 2015, pp. 39–58.

Köhnke, Klaus Christian. *Entstehung und Aufstieg des Neukantianismus*. Frankfurt: Suhrkamp, 1986.

Koyré, Alexandre. "Galileo and Plato", Journal of the History of Ideas, 4, (1943), 400–428.

Holzhey, Ulrich. "Cohen and the Marburg School in Context". In: Reiner Munk (ed.), *Hermann Cohen's Critical Idealism*. Dordrecht: Springer 2005, 3–37.

Kant, Immanuel. *Kants gesammelte Schriften*, hrsg. von der Königlich Preußischen Akademie der Wissenschaften. Berlin *et al.*: De Gruyter, 1900– (=KgS).

Laks, André. "Avant Natorp. L'interprétation des idées platoniciennes chez H. Cohen". In Ada Neschke-Hentschke (éd.), *Images de Platon et lectures de ses œuvres*. Peeters, Louvain, 339–60.

Lange, Friedrich. *Geschichte des Materialismus und Kritik seiner Bedeutung in der Gegenwart.* Iserlohn: Baedeker, 1866 ($1875^2$, 2 vols).

Lazarus, Moritz. "Einige synthetische Gedanken zur Völkerpsychologie". *Zeitschrift für Völkerpsychologie und Sprachwissenschaft*, 3 (1865): 1–94.

Lembeck, Karl-Heinz. *Platon in Marburg*. Würzburg: Königshausen & Neumann, 1994.

Lotze, Hermann. *System der Philosophie. Erster Teil.* Leipzig: Hirzel, 1874.

Luft, Sebastian (ed.). *The Neo-Kantian Reader*. Abingdon: Routledge, 2014.

Meyerson, Émile. *De l'explication dans les sciences*. Paris: Payot, 1921. Engl. tr. Dordrecht: Kluwer, 1991.

Meyerson, Émile. *La déduction relativiste*. Paris: Payot, 1925. Engl. tr. Dordrecht: Kluwer, 1985.

Natorp, Paul. "Galilei als Philosoph. Eine Skizze". *Philosophische Monatshefte*, 18, 1882, 193–229.

Natorp, Paul. *Platos Ideenlehre*. Leipzig: Meiner, $1921^2$ [$1903^1$], engl. tr. by V. Politis and J. Connolly, Sankt Augustin: Academia Verlag, 2004.

Natorp, Paul. *Die logischen Grundlagen der exakten Wissenschaften*. Leipzig-Berlin: Teubber, 1910.

Pais, Abraham. *«Subtle is the Lord...» The Science and the Life of Albert Einstein*. Oxford: Oxford University Press, 1982.

Patton, Lydia. *Hermann Cohen's History and Philosophy of Science*. Ph.D. Thesis, 2004.

Pecere, Paolo. "Fisica quantistica e realtà." In: Niccolò Argentieri, Angelo Bassi, Paolo Pecere, *Meccanica quantistica rappresentazione realtà*. Napoli: Bibliopolis, 2012, 67–178.

Pecere, Paolo. "Physiological Kantianism and the organization of the mind". *Intellectual History Review*, 2020, https://doi.org/10.1080/17496977.2020.1784596.

Plato. *Complete Works*, ed. by J.M. Cooper, D.S. Hutchinson. Indianapolis/Cambridge: Hackett, 1997.

Poincaré, Henri. *La science et l'hypothèse*. Paris: Flammarion, 1908.

Richardson, Alan. “Ernst Cassirer and Michael Friedman: Kantian or Hegelian Dynamics of Reason?” In: R. A. Makkreel, S. Luft (eds.), *Neo-Kantianism and Contemporary Philosophy*, Bloomington and Indianapolis: Indiana University Press, 2010, 279–294.

Ryckman, Thomas. *The Reign of Relativity*. Oxford: Oxford University Press, 2005.

Ryckman, Thomas. “Cassirer and Dirac on the Symbolic Method in Quantum Mechanics”. *Journal for the History of Analytical Philosophy,* 6 (3) (2018): 214-39.

Scholz, Erhard. “The Changing Concept of Matter in Hermann Weyl’s Thought 1918–1930”. In: V. F. Hendricks *et al*. (eds.), *Interactions*. Dordrecht: Springer, 2006, 281–306.

Trabattoni, Franco. “La dottrina platonica delle idee come fondamento epistemologico dell’impresa scientifica? Un percorso da Kant a Natorp”. In Riccardo Chiaradonna (ed.), *Il platonismo e le scienze*. Roma: Carocci, 2012, 165–91.

Trendelenburg, Adolf. *Logische Untersuchungen*. Leipzig: Hirzel, 1862.

Weyl, Hermann. *Space Time Matter*, transl. of the 4th ed. by H. L. Brose. Mineola (NY): Dover, 1952.

Weyl, Hermann. *Philosophy of Mathematics and Natural Science*. Princeton: Princeton University Press, 1949.