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Article

Galileo, Plato and the Scientific Revolution: The Origins of Galileo’s Platonism Thesis in the Historiography of Science

Giorgio Matteoli¹

Abstract:

This paper retraces the history of one of the founding thesis of the modern historiography of science (Galileo’s Platonism thesis), starting from its first appearance in the context of the Neo-Kantian school of Marburg up to its final assessment in the works of Koyré. Following these debates provides us with a privileged point of view to observe the emergence of the concept of scientific revolution, which reached its current popular form in Koyré’s *Galileo Studies*.

Keywords: Galileo; Plato; Cassirer; Koyré; Scientific Revolution

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The Neo-Kantian Origins of the GP Thesis

In 1994 a voluminous book called *The Scientific Revolution* was published. Its author, Hendrik Floris Cohen, aimed to reconstruct the genesis, development and institutionalization of the historiography of science during the XX century, filling a significant gap in this area of scholarly research. The hypothesis that structured his narrative was already evident from the title: what brought together on common intellectual ground philosophers, scientists, historians and sociologists (plus various combinations of those figures, still quite frequent at that time) had been the reflection on the almost ideal typical key-concept of *scientific revolution*:

Efforts to arrive at a historical understanding of the birth of modern science speeded up considerably between 1924 and c. 1950, as a result of two closely related events. One was the rise and subsequent rapid spread of the concept of the “Scientific Revolution” as an analytical tool expressly forged for grasping the essence of the emergence of modern science. The other was the history of science turning into a

¹ Giorgio Matteoli [Orcid: 0000-0002-7778-9519] is a Ph.D. Candidate in the Northwestern Italian Philosophy Consortium (FINO) at the University of Turin. Address: Via Sant’Ottavio, 20, 10124 Torino TO. Italy. E-mail: gmatteoli1@gmail.com

professional academic discipline—a process that, coincident with fresh academic opportunities to be sure, crystallized largely out of the new concept of the Scientific Revolution. (Cohen 1994, 1-2)

Before this expression reached common use after the Second World War, the question of the origins of modern science had to go through a long phase of gestation, in which the problem to settle seemed to be dealing with the justification of the continuity and the rationality of the scientific enterprise through its historical development. Thomas Kuhn once referred to this period before the war in terms of a “historiographical revolution” in the way of thinking science and its past, thanks to the work of philosophers and historians such as Ernst Cassirer, Annaliese Maier, Edwin Burttt and Alexandre Koyré (Kuhn 1970a, 69). The revolution consisted in the fact that for the first time historians seriously started to question the origins of that four hundred years practice we call “modern science”, going back to the primary sources without renouncing to a philosophical reflection on its cultural and epochal meaning. Unfortunately, though, these authors are praised more than they are really studied. Taking a closer look, we can see that the concept of scientific revolution emerged and crystallized in the context of a precise debate and philosophical reflection on the Platonic character of Galilean science; and this story – the emergence of the concept of scientific revolution from the Galileo's Platonism thesis debates – is what we briefly want to retrace in the following pages.

At the beginning of the XX century, the continuist thesis (i.e. the idea that knowledge progresses through time continuously and cumulatively, without significant ruptures, shifts or losses of cognitive material) was quite widespread thanks to the works of Pierre Duhem, a dedicated historian of science and physicist. He claimed that modern experimental science, and in particular Galileo's theory of movement, had no revolutionary meaning whatsoever since its essential features were already present in the *impetus* theory, dating back to the *doctores parisienses* Jean Buridan, Nicole d'Oresme and Albert of Saxony. Duhem's radical thesis contributed, on the one hand, to raise a broad interest towards Medieval and Renaissance science, until then barely studied or ignored *tout court* as pre-scientific. On the other hand, it pushed many epistemologists and historians to consider the hypothesis that scientific progress could imply some degree of discontinuity, though in a different sense than it was conceived by Enlightenment and Positivist thinkers in the XVIII and XIX century, as a mere struggle between scientific truth and religious or mystical superstition.

The Neo-Kantian Marburg school is a good example, among many others, of the effort to support and justify a certain refined version of the continuist thesis. The problem of the so-called logic of science had been a central concern of the Neo-Kantian research program since the first writings of Hermann Cohen and Paul Natorp; but it is especially interesting to follow the intellectual path of Ernst Cassirer in that context, since it shows the progressive questioning of the radical continuist thesis in the history of science, up until when he eventually came to use the term “revolution” (probably inspired by Koyré) at the end of the Thirties.

Most importantly, it is in the Marburg school that the Galileo's Platonism thesis was first formulated by Natorp, in an article called *Galileo as Philosopher* (1882). For Natorp, Galileo was the true founder of the modern idea of *law*, meant as a mathematical necessary connection between phenomena. But it is only with Cassirer, who took inspiration from his teacher, that Galileo's Platonism thesis was refined and systematized in the wider framework of the history of science. According to Cassirer, in fact, the historical figure that stands almost as a prism at the beginning of modernity, conveying all the many philosophical and scientific tendencies of the previous epochs in the bright beam of modern science is Galileo Galilei: “Had Galileo died as a child the evolution of modern thought would have been retarded for decades and would almost certainly have differed in many fundamental aspects” (Cassirer 1942a, 5). All the main exponents of modern philosophical and scientific idealism had later

worked in the wake of his functional redefinition of scientific knowledge. It is the case of Descartes, Spinoza, Gassendi, Hobbes, Leibniz and Kant, who explicitly acknowledged this fact in the preface to the second edition of his *Critique of Pure Reason*. It is evident then that to follow the progressive evolution of Cassirer's interpretation of Galilean science in the forty years that go from the publication of *The Problem of Knowledge* (1906/7) to the nourished group of articles on Galileo written during the Forties allows us to reach a privileged point of view on what has been called the "Neo-Kantian tradition in the history of scientific thought" (Cohen 1994, 168; Friedman 2010; Ferrari 2018).

In the first volume of *The Problem of Knowledge* Cassirer interpreted the whole history of science not only as a progressive shift from a substantial to a functional conception of knowledge but also as an endless alternation of various guises of "Aristotelianisms" and "Platonisms". The most important step in this process was taken by Galileo, the true founder of modernity, with his peculiar reinterpretation of the philosophy of Plato (Cassirer 1910-1911, 316). Cassirer calls this feature of Galilean science "Physical Platonism", and it praises it for the fact that it was able to go beyond Plato on one essential point: the ideality of the mathematical part of knowledge was now integrated with the empirical and experimental side, the Kantian *Bathos der Erfahrung* so dear to Marburg Neo-Kantians:

The Platonic *ideal* of knowledge is valid for Galileo as well: it can be an object for science what constantly keeps its unity. But if this idea for Plato was fully confirmed only in mathematics, now we turn directly and with more precision to physical objects. It is easy to understand this evolution if we consider the way in which Galileo came to his *concept* of nature. He doesn't connect in an exterior unity a manifold of facts and observations, but he delimits and determines in a rigorous way the materials of experience according to geometrical *criteria*. To nature, in the proper scientific sense of the term, only belong true and necessary things, i.e. those that cannot be otherwise. (Cassirer 1910-1911, 324-325)

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Galileo and Plato share a fundamental idea: they both understand the laws of nature not as something that is immediately given to us or capable of being concretely shown, but as *ideal* laws that can never be fully verified in the changing realm of nature. Nevertheless, for Galileo, this does not jeopardize their validity and objectivity: the fact that in nature we never encounter a body that falls indefinitely in the void does not make the principle of inertia less valid.

The epochality of Galilean science (prepared by Kepler's and Leonardo Da Vinci's insights to be sure) had mainly to do with the creation of a new concept of experience, a renewed notion of the relation between the subject of knowledge and its object, nature. This new conception emerged in contrast with both the old Aristotelian idea of science and the Renaissance *philosophia naturalis*, still too "superstitious" and bound to the doctrine of "occult forces", so that it could not reach the rigorous abstraction of mathematical analysis. According to Galileo even Kepler was still too close to the mystical thought of these Renaissance currents, although he was the first one to discover and apply through functional reasoning the new concept of "law", starting to fill the Platonic gap between the physical explanation of real causes and the hypothetico-deductive representation of mathematics (Cassirer 1910-1911, 317-318, 356).

Only with Galileo did mathematical science of nature acquire its true modern form. Already in this early stage of Cassirer's intellectual production the development of science is conceived as a complex process, neither fully continuous nor discontinuous, but always exhibiting different levels of continuity and discontinuity (cf. Gigliotti 2006). Galileo's case is taken as a perfect example of this phenomenon. In *The Problem of Knowledge* Cassirer uses four hundred pages (before coming to Galileo's chapter on the birth of modern science) to show how tight the bonds that linked Galileo to his historical context were. However, to

retrace the genesis of Galileo's thought does not amount to fully account for the importance of his contribution to the history of science. What is truly unprecedented in Galilean science is precisely the Platonic redefinition of the ratio between the ideal and the empirical side of knowledge, which allows Galileo to bring to completion the conceptualization of the idea of "physical law", i.e. the functional mathematical relationship that isolates in the rhapsodic and chaotic flux of empirical variations the *form* of such variations:

Galileo's system, being entirely based on the interpenetration of experience and reasoning, finally overcomes the ancient struggle between "empiricism" and "rationalism", now revealed as vague and unfruitful. Another problem is posed now, and much deeper, i.e. if one should start with things or with relations, from the existence or the forms of concatenation. Against the substantialistic conception of the world, a new one rises, which has its roots in the concept of function. It is clear now that it is not possible to understand the history of modern philosophy in its development without considering its relationship with exact science. (Cassirer 1910-1911, 402)

The Problem of Knowledge had mainly focused on those aspects of Galileo's work that were strictly scientific; with *The Individual and the Cosmos in Renaissance Philosophy* (1927) the Cassirerian interpretation of the origins of modern science came to a much more nuanced, refined and articulated form (also thanks to his decennial collaboration with the *Kulturwissenschaftliche Bibliothek Warburg* in Hamburg) integrating the reflection on Galilean science in the wider framework of Renaissance culture. Moreover, on a more theoretical side, during the Twenties Cassirer had been working on his philosophy of symbolic forms. Modern science was then conceived as one of the many symbolic forms that can give form to reality: its birth is not thought as a linear historical passage from the prevalence of one symbolic form, mythical or religious, to the scientific one. On the contrary, *The Individual and the Cosmos* presents the outset of modernity in complex terms, as a progressive redefinition in the manifold of cultural forms that see science, art, religion and philosophy working in a mutual and collaborative joint effort.

According to Cassirer, in the "struggle" to separate "what is 'necessary' from what is 'accidental', what works according to laws from what is arbitrary and imaginative", the purely intellectual and scientific motives were not the only nor the most important ones: "the logic of mathematics goes hand in hand with the *theory of art*. [...] Mathematics and art now agree upon the same fundamental requirement: the requirement of 'form'" (Cassirer 2000, 152). Galileo did not renounce to Renaissance ideals: today we tend to consider him only as a great physicist, but in doing so we separate research areas that at his time were conceived as bound in a "indissoluble unit" (Cassirer 2000, 153).

Likewise, the question of continuity is reconsidered:

The continuity of this process does not imply that the *systematic* succession of thoughts is represented and reflected by a *temporal* succession. We are not dealing with a continuous temporal "progress" that leads in a straight line to some specific goal. Not only do the old and new proceed together for long periods of time, but both continually merge with each other. One can, therefore, speak of "development" only in the sense that the individual thoughts, precisely through this process of merging and separating, gradually distinguish themselves from each other more sharply and emerge in definite, *typical* configurations. These typical configurations make clear to us the immanent forward movement of thought, which by no means necessarily corresponds to its temporal and empirical course. (Cassirer 2000, 102)

Cassirer takes a step beyond Duhem, an author he studied well and appreciated for his epistemological studies. Despite Duhem's "careful and detailed analysis" on the importance of the work of the late nominalists for modern statics and dynamics, for Cassirer, the "systematic meaning" of the latter was "overestimated". Oresme and Buridan surely opened the way to modern science, weakening the authority of Aristotle; but they never truly built a new constructive theory of nature (Cassirer 1942b, 315).²

On the one hand, Cassirer keeps stressing the importance of the rational continuity that critical analysis retraces in the history of science; on the other hand, he explicitly acknowledges the non-linearity and only partial cumulativeness of the process of knowledge, in which we constantly encounter mistakes, impasses, false starts and consistent losses of information. Nevertheless, thanks to the universality of its logical functions, reason can always make an effort to retrace or construe trend lines, persistent problems, immanent teleologies that somehow guarantee continuity through time. The *salvare apparentia* motto should not be intended instrumentally, as Duhem did, but transcendently (Ferrari 2012, 117). Continuity and discontinuity both belong to the history of science according to Cassirer. Continuity is maintained regardless of the changes which can occur – but new bold hypotheses can question part of the previous set of belief, and they can even give rise to revolutions. The change is not interpreted in a substantial sense, but functionally: in a Kantian epistemological guise, it is our knowledge that is reorganized in this process, not the object we study. Or, with Pascal: *qu'on ne me dise pas que je n'ai rien dit de nouveau, la disposition de matières est nouvelle*.

Cassirer kept studying these themes until the very end of his life, especially during his American exile in the Forties (Cassirer 1937; Cassirer 1940; Cassirer 1942a; Cassirer 1943; Cassirer 1946). There are no substantial differences with *The Problem of Knowledge* and *The Individual and the Cosmos*, except for a more accentuated emphasis on the idea of scientific revolution; but these articles are highly interesting nonetheless, because they show Cassirer's attempt to get involved in the newly formed international community of professional historians of science, publishing on important journals (the *Journal of the History of Ideas, Scientia*) or dialoguing with established scholars (George Sarton, John Randall, Alexandre Koyré) through summaries and reviews about what he considered to be his most important contribution to this field: his studies on Galileo's Platonism.

The Concept and the Problem of Truth in Galileo (1937) offers a brief recognition of the "images of the Galilean revolution" in the centuries following the XVII. During his life, Galileo was known especially for his astronomical studies: the discovery of Jupiter's satellites, the observation of Venus' phases, the rings of Saturn and the Milky Way. Only after the *Dialogue* had been widely received by the European intellectual community Galileo started being considered as an advocate of the Copernican doctrine. In the following century, the century of Hobbes, Leibniz, d'Alembert, Lagrange and up until the XIX century, Galileo became the great pioneer and theoretical founder of dynamics: "if Galileo managed to found dynamics, it is because he searched for it by a completely different way. His works on physics are the result [...] of his new concept and ideal of truth" (Cassirer 1937, 57-59). For Cassirer, as will be for Koyré, Galileo is a philosopher before being a scientist: to found his dynamics, he first had to put forth a new logic. And even if he never formulated a systematic theory of knowledge, the philosophical meaning of his new concept of truth would have had a widespread resonance beyond the limits of the scientific domain, reaching all the fields of modern culture, like the philosophy of religion of Herbert of Cherbury and the philosophy of right that Hugo Grotius founded (Cassirer 1937, 64-65).

Mathematical Mysticism and Mathematical Science of Nature (1940) offers Cassirer's ultimate reflection on the concept of scientific revolution. He claims that the "new ideal of

² On Cassirer and Duhem cf. (Ferrari 1995; Seidengart 1995).

'exactness'" represented by the new mathematical science of nature could not emerge without a true "'leap' of thought":

The history of human knowledge always presents some epochs – which belong to the most significant and important ones – in which knowledge does not really seem to enlarge its extension, but it rather appears to modify its content and its meaning. Instead of a simple quantitative growth, we witness a sudden qualitative "change"; instead of an evolution we experiment an unexpected revolution (Cassirer 1940, 249).

This does not mean that all the bridges with previous epochs of knowledge are burnt: "there can never be anything for us that is absolutely immediate. As historians of the mind, we can never point our finger on the exact spot where the old disappears, making room for the new. Every historical demarcation is and remains arbitrary if it is meant in this sense" (Cassirer 1940, 249). Even though the historical development never really suspends its continuity, there are historical figures such as Galileo (or Michelangelo, Dante, Newton, Kant) that emerge from the "Heraclitean flux of things" and modify the course of events in a peculiar and unprecedented way (Cassirer 1940, 251). Cassirer's mixture of continuism and discontinuism can be defined, so to speak, as *soritical*: we easily understand the extremes of the historical spectrum, so that it is not hard to understand in which sense a man of the XII century and one of the XIX belong to entirely different epochs; but we can never identify with precision the exact moment in which, for example, the Middle Ages end and the Renaissance starts.

Cassirer also goes back to the problem of Galileo's Platonism, contrasting one of the first attempts to criticize this idea – Eduard Strong's *Procedures and Metaphysics* (Strong 1936). Strong tried to scale back the role of Platonism and in general the importance of the purely theoretical aspects in the birth of modern science, highlighting the more immanent, technical and concrete features of it. In 1940, Cassirer could already rely on the studies of Koyré to substantiate his hypothesis, and he presented it more straightforwardly in *Galileo's Platonism*, published posthumously in 1946 for the George Sarton's *Festschrift*.

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Can Galileo be considered a Platonist? "This question is often posed and warmly discussed in the most recent literature. But we are far from reaching a universally shared solution" (Cassirer 1946, 355). When historians of science discuss the birth of modern science – Cassirer goes on – Platonism should not become a *slogan*. More than 2000 years divide us from the historical Plato, and in the meantime the term "Platonic" has gained a strong polysemy. If we do not make clear what it means, we risk giving rise to pointless ambiguities and idle disputes. There can be

a skeptical Platonism – the Platonism of the late Academy – and a mystical Platonism such as Plotinus' and the Neo-Platonist schools'; [...] a religious Platonism (Saint Augustine) and a logical Platonism (Scotus Eriugena, the Medieval realists); [...] the Platonism of Marsilio Ficino, Malebranche and the Cambridge Platonists; [...] a romantic Platonism in Schelling's dialogue *Bruno* and in his oration on arts and nature. As a matter of fact, all these doctrines are not only divergent but, in many ways, openly contrasting. And even if we could find a common denominator among the skeptical, the mystical, the Christian and the romantic Platonism, this would not help us solve our problem. Galileo's Platonism, if it exists, has nothing to do with all these other types; it belongs to a whole different world. (Cassirer 1946, 355)

Galileo's Platonism does not resemble any of the previous kinds of Platonism, and cannot be offhandedly identified with a mere "mathematicism": "his was not a metaphysical Platonism, but a physical one", and in this feature resides its radical and even revolutionary novelty, for it was Plato himself to establish the total incommensurability, the *chorismos*

between the sensible and the intelligible world. Galileo's theory and practice of science overcame this difficulty, establishing the concrete possibility of describing the sensible world through necessary demonstrations, and in so doing reach truths that were certain. But according to Cassirer Galilean science is ultimately Platonic, since it shares with Plato the belief in the importance of the *hypothetical-deductive method* (Cassirer 1946, 357, 366-367).

After Cassirer, before Koyré

The correlation between Galilean science and the philosophy of Plato had been established for the first time in the context of the Neo-Kantian school of Marburg. But before dealing with Koyré's version of the GP thesis, which happened to become the standard version, we should remind that other scholars worked on the path started by the Neo-Kantians, after Cassirer and before Koyré – even though they did not become quite as popular.

As Koyré acknowledges in the opening passage of his *Galileo Studies*, the influence of Plato on Galileo's thought and on the structure of some of his works had been noticed by a German translator of the *Dialogue Concerning the Two Chief World Systems*, Emil Strauss, at the end of the XIX century (Galilei 1891, XLIX). Moreover, a great source of inspiration for Koyré's treatment of the GP thesis and in general of the scientific revolution was Edwin Arthur Burt's book *The Metaphysical Foundations of Modern Physical Science*, published in 1924. The main thesis which Burt put forth was that it is impossible to separate the metaphysical and religious sub-structure of modern science from its strictly "scientific" outcomes. And that was true not only for known neo-platonists such as Copernicus and Kepler but also for authors like Galileo, Newton and Descartes (Burt 1924, 25-35). So Burt recognized that "the Neo-Platonic background of the mathematical and astronomical development of the times has strongly penetrated the mind of the Italian scientist [Galileo] as in the case of so many lesser figures" (Burt 1924, 82); but he failed to distinguish (as Koyré would later do, following Brunschvicg 1912, 67-70) between at least two kinds of Platonic traditions, namely, a "mystical-speculative" one and a "mathematical-scientific" one. For Koyré, as we will see, Galileo was totally foreign to the first, which was typically a feature of the Neoplatonic Florentine Academy.³

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While Burt's and Koyré's accounts are very similar (apart from the differences we just mentioned) Leonardo Olschki's *Geschichte der neusprachlichen wissenschaftlichen Literatur* (and especially the third volume, *Galilei und seine Zeit*) stands out for his originality when confronted with the others. The main goal of this monumental book – in many ways similar to Cassirer's *Erkenntnisproblem*, to which it is openly inspired – was "to experience how the development of the sciences stands in relation to the linguistic development, and what relationships exist between the sciences and literature" (Olschki 1927, I, 4). Olschki was trained as a philologist, and he employed his expertise in this field

to discover the cultural preconditions of scientific development; to discover the interactions between language and thought for mutual enrichment and perfection; to find the relationships between scientific and literary forms of representation, and to point the way that allows us to penetrate into the most mysterious and intimate atmosphere in which recent scientific aspirations have come to maturity and final expression. (Olschki 1927, I, 6)

³ The distinction between the different kind of Platonisms during the Renaissance and the Early-Modern Age is a difficult theme; Eugenio Garin (Garin 1973, 196; Garin 2008, 312) criticized Koyré's distinction, claiming that the difference between the two traditions is less sharp than it could seem; on the other hand, Paolo Casini (Casini 1987, 97) agreed with Koyré. A discussion of this theme can be found in Shea 1972, 74ff and Baroncini 1978.

What Olschki aimed to achieve by the examination of the terminology, the style and the form of literary representation of each technical and scientific writer was “to show in its context the development by which the alogic elements of scientific thought and representation – psychological, aesthetic, moral and metaphysical – are gradually eliminated in favour of unambiguous objectivity” (Olschki 1927, I, 8). Just like for Cassirer, Burt and Koyré, also for Olschki the most important feature of this great change in European culture was linked to the new significance and centrality attributed to mathematics in natural research. The protagonist of this shift was once again Galileo, “the first true modern experimental scientist”, who brought about the emergence of a new scientific method through an “idealization of the experienced and the concrete”, which amounted to a “Platonic method of contemplating nature, which to this day, in this particular application, perhaps without one being aware of it, has retained its validity in the whole of experimental physics” (Olschki 1927, III, 164-165).

Olschki's overall interpretation of the birth of modern science then belongs to the discontinuist party, for he conceives his study as “a history of the renewal (*Erneuerung*) of scientific thought and of the scientific dialectic within the framework of European cultural history” (Olschki 1927, I, 6). However, his account of the causes of the scientific revolution reveals a less intellectualistic stance than the ones we encounter in the other authors examined, especially when it comes to Galileo. Olschki's view was more akin to that of Ernst Mach (1883) and Edgar Zilsel (2003) on that matter, and it has recently been reconsidered, coming back into fashion (cf. Valleriani 2010). The new scientific spirit has its origins in the work of “artisans and engineers”; it “begins with the applied sciences and the empirical sciences in order to find its own way to pure scientific abstractions beyond the limits of practical necessities” (Olschki 1927, I, 6). This conception completely reversed the cause-effect order of explanation that Koyré would have given of the scientific revolution. And that is why Koyré criticized Olschki in his *Galileo Studies* (Koyré 1939, 213) regardless of his favourable review of the book a decade earlier (Koyré 1930).

Koyré and the GP Thesis

The way in which Koyré formulated his own version of Galileo's Platonism thesis towards the end of the Thirties is the most known and significant result of his studies in the history of science. Even though in the last decades it has been deeply reevaluated and criticized, it is impossible to ignore the outstanding impulse it has given, either as a conceptual framework (Banfi 1949, Kuhn 1957, Kuhn 1970a, Shea 1972, Galluzzi 1973, Torrini 1993, Hankins 2000) or as a controversial target (Geymonat 1957, Randall 1961, Girill 1970, Drake 1970, Wallace 1981, Høyrup 1990, Machamer 1998, Dollo 2003) not only to Galilean studies in particular, but also to the overall shape and structure that the history of science as a discipline has taken during the last century.

Most importantly, the Platonic interpretation of Galilean science had one major consequence for the Twentieth century's historiography of science, as Hendrik Floris Cohen acknowledged (Cohen 1994, 2). Namely, this thesis worked as a kind of intellectual presupposition or even as a true condition of possibility for some momentous ways of reappraising the birth of modern science in terms of discontinuity and rupture with ancient and Medieval science (above all, that of Thomas Kuhn) which eventually brought to the large-scale dissemination of the concept of *scientific revolution* to describe the complex set of events that occurred more or less between the publication of Copernicus' *De revolutionibus* in 1543 and the intellectual aftermaths of Newton's *Principia mathematica* in the years following its publication in 1687. To be sure, the concept of revolution had already been used during the XVIII and XIX centuries to describe certain groundbreaking episodes that occurred

in some particular sciences (Cohen 1976, Cohen 1987). But it is only with Koyré that the expression “scientific revolution” was widely used for the first time, obtaining the current meaning and fame.

For Koyré, the GP thesis and the discontinuity thesis, i.e. the idea that the birth of modern science has to be understood in terms of a revolutionary process (rather than an evolutionary or continuous one) were strictly intertwined. There is a strong philosophical presupposition that supports this interpretation, which could already be found in Cassirer's works: the idea that “describing the clash between Platonism and Aristotelianism in all the width and depth of its conceptual contrasts would amount to making the history of modern thought” (Cassirer 1910-11, 80). In fact, if we conceive the ancient and Medieval science as predominantly Aristotelian, then to consider the birth of modern science as a “return to Plato” or a “*revanche*” of Platonism ought to imply that we interpret this passage as a process which brings along a certain degree of discontinuity (Koyré 1939, 266, 269, 273-81). Moreover, it is Koyré himself who framed the question in these terms. For example, in a long review of Alistair Crombie's book on Grosseteste he stated that

The problem of the origins of modern science and its relationship with Medieval science is still a *quaestio disputata*. Both the partisans of continuous evolution and those of a revolution are steady in their positions and seem incapable of convincing one another. And this, I think, happens not because they disagree on facts, but because they disagree on the very essence of modern science and, consequently, on the relative importance of certain fundamental characteristics of it. What one party interprets as a difference of degree, the other sees as a difference of nature. (Koyré 1956, 61)

There is no doubt that Koyré belongs to the discontinuist party. He interprets the scientific revolution as a complex phenomenon, a profound intellectual and philosophical transformation that consists of different moments and characteristics: the mathematization of reality; a conception of space and time as infinite objects; a theoretical experimentalism; the shift from a world of “more or less” to a “universe of precision”. But all these aspects can be reduced to two, according to Koyré:

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We believe that the intellectual attitude of classical science can be characterized by two intertwined aspects: the geometrization of space and the destruction of the Cosmos, i.e. the disappearance from science of every consideration based on this concept and the substitution of the abstract space of Euclidean geometry to the concrete space of pre-Galilean physics. (Koyré 1939, 15)

These attributes, stated for the first time in his *Galileo Studies*, will remain essentially unvaried every time Koyré will return on this theme in his following works. The “destruction of the Cosmos” is the “destruction of the idea of a hierarchically-ordered finite world-structure”, in favour of an “open, indefinite and even infinite universe, united and governed by the same universal laws” in which “all things are on the same level of Being” (Koyré 1943, 403). The two processes are linked because the geometrization of space necessarily leads to the destruction of the old Cosmos. For example, in a homogeneous space such as the one of Euclidean geometry, it is impossible to think the separation (central for the pre-Galilean science) of terrestrial and celestial space. But according to Koyré the scientific revolution is first and foremost a “*philosophical revolution*” (Koyré 1957, 2); and the philosophy in question is that of Plato, although it appears to have acquired a very peculiar guise in authors such as Copernicus, Bruno, Descartes, Torricelli, Newton and of course Galileo, the true symbol and pioneer of this new way of thought.

The main feature of Galileo's Platonism is what Koyré calls “mathematicism”. The role of mathematics in natural research was the *vexata quaestio* that divided Platonists and

Aristotelianists already at Galileo's time (Koyré 1943b, 347). One of Galileo's colleagues and friends, Jacopo Mazzoni, once reminded that "the supreme question was to know if one had to be a Platonist or an Aristotelianist" (Koyré 2016, 98). How to choose between the two philosophies?

We can see it clearly: for the philosophical and scientific conscience of the time [...] if one proclaims the *superior value* of mathematics, if, moreover, one attributes to it a real value and a dominant position in and for physics, then one is a Platonist; if, on the contrary, one sees mathematics as an "abstract" science, and as a consequence it gives it a *lesser value* among the sciences – physics and metaphysics – that deal with reality, if, in particular, one claims to ground physics directly on experience, attributing to mathematics only a handmaid position, then one is an Aristotelian. (Koyré 1939, 279)

Galileo could not ignore this opposition. When he was a student in Pisa, he followed the courses of Francesco Buonamici, who explicitly taught that "the *quaestio* of the role and nature of mathematics is the watershed between Aristotle and Plato". We know from our historical perspective which side Galileo (and the whole modern science with him) chose to follow, making "the advent of classical science – even if we ignore it – a return to Plato" (Koyré 1939, 279).

To be sure, for a strict Platonist, it would be absurd to apply mathematics to the physical world since ideal and sensible objects are entirely incommensurable in that view.⁴ But this is precisely what Galileo's revolution brought about. As Cassirer remarked, "if Galileo's Platonism exists, it does not have much in common with any previous "Platonism"; it belongs to an entirely different world" (Cassirer 1946, 355).

Another reason provided by Koyré in favour of the GP thesis has to do with the literary form of Galileo's works, and especially with the *Dialogue Concerning the Two Chief World Systems*. Koyré suggests that Galileo took inspiration from the Platonic dialogues, and not from the dialogue-form in general, which was quite popular at the time. It is known that for Plato the choice of rendering his philosophy in a dialogical form was linked to his theory of knowledge, i.e. the innatism related to the theory of reminiscence. According to Koyré, Galileo shared this broad epistemological view in the domain of mathematical ideas:

It has not been sufficiently stressed that for Galileo the fundamental ideas of science (the mathematical ideas) are all *innate ideas*. This term, to be sure, cannot be found in his works: but the whole structure of the *Dialogue*, conceived as a conscient imitation of a Platonic dialogue; Salviati's application of the Socratic method; and the great stress posed on the impossibility of teaching what someone does not already know are – or should be – widely sufficient. (Koyré 1937, 44)

The literary form of the *Dialogue*, the "Platonic innuendos, disseminated all along with the book", the incipit that lingers on a pseudo-platonic cosmological myth, the allusions to the Socratic method – all these clues aim to tell us: "Beware! In the epochal struggle which opposes the two great philosophies, we stand for Plato" (Koyré 1939, 213). This is clear, for example, when Salviati recalls the "experience" of the fall of a body from the mast of a ship, i.e. the example of the actualization, through the application of the Socratic method, of a piece of knowledge that was until that moment "unconscious":

SALVIATI: Without experiment, I am sure that the effect will happen as I tell you, because it must happen that way; and I might add that you yourself also know that it

⁴ This objection has been raised by Girill 1970, 502-505.

cannot happen otherwise, no matter how you may pretend not to know it – or give that impression. But I am so handy at picking people's brains that I shall make you confess this in spite of yourself. (Galilei 1967, 145)

Before turning to experience – Koyré explains – a man already knows the truth, so that “experience is useless because before any experience we are already in possession the knowledge we are seeking for” (Koyré 1943b, 346). However, sometimes it could happen that we do not know that we already know something – as so frequently happens to Simplicio in the course of the book. In that case, it is sufficient for us to *remember*, stimulated by the proper questions:

The proof that [good physics is done *a priori*] is in the fact that [...] Simplicio himself does not need to resort to experience to acknowledge the truth. [...] He knows the truth, without thereby realizing that he does; so for him it is not necessary to learn it (which would be completely impossible); it is sufficient posing the right questions to him, to show him (and us) that we already know it. (Koyré 1939, 227)

Moreover, it is Galileo himself (through the mouth of Simplicio) that underlines his closeness to Platonism in a famous passage:

SIMPLICIO: I have frequently studied your manner of arguing, which gives me the impression that you lean toward Plato's opinion that *nostrum scire sit quoddam reminisci*. So please remove all question for me by telling me your idea of this.

SALVIATI: How I feel about Plato's opinion I can indicate to you by means of words and also by deeds. In my previous arguments, I have more than once explained myself with deeds. I shall pursue the same method in the matter at hand, which may then serve as an example, making it easier for you to comprehend my ideas about the acquisition of knowledge. (Galilei 1967, 190-191)

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The example that follows, to which Salviati is referring to, is the classic counterexample to the Aristotelian theory of motion (projectiles motion); Simplicio, like the slave in Plato's *Meno*, will come to understand the truth by reasoning, guided by Salviati's questions. So, Galileo did much more than just pledge himself a partisan of Platonic epistemology; his findings “had demonstrated the truth of Platonism with facts” (Koyré 1939, 287-288). Here lies the meaning of the “theoreticist” Koyrean interpretation of Galilean experimentalism: the thought-experiment comes first and constitutes the foundation of the real experiment – not inductively, but completely *a priori* (cf. Detel 1979, De Caro 1992, De Caro 1996).

If experiences are not guided by reason's mathematical reflection, they represent an obstacle instead of a proof on the path towards the truth (Ferrarin 2014, 91; Clavelin 1968, 432; Rossi 1972, 103-128). This is a strong argument in favour of Galileo's Platonism: progressing *ex suppositione*, through hypotheses that are geometrically constructed *a priori*, Galileo's reasoning remains valid even in the case in which experience does not meet the expectations, as Galileo once remarked in a letter to the mathematician Carcavy. Archimedes' demonstrations on the nature of spirals would still be true even if in there were no objects moving in that way; the laws of dynamics would hold even if we could never observe objects falling through the void with the same speed (5 June 1637, in Galileo 1890-1909, XVII, 89-93).

At any rate, during the Forties and the Fifties (with new inspiration coming from his late Newtonian studies) Koyré progressively scaled back his thesis of the “revolution without experience”, giving a more nuanced interpretation of the philosophical influences at the origins of modern science, adding a reflection on Archimedianism and Democriteanism to the picture. “Good physics is done *a priori*. But it must beware, as I already said, of the temptation

of falling into indefinite concretization, and it should not let imagination replace theory", which in turn always has to be "in touch with real experience" (Koyré 1973, 271).

Regardless of whether the book of nature is written in the language of mathematics (as Koyré suggested) or it is read as such (Cassirer), or whether it is ordered, copied, interpreted, intuited in that way, it is still worthy of reflection that

The problem of experimentation, if we can say so, has an evident symbolic dimension. This is how we can explain the vehemence of some controversies regarding who is generally considered the founding father of modern physics. Every historian and every epistemologist care to emphasize what the "Galileo case" shows and confirm of their own conception of "science", of "reason", of "experience". [...] There are multiple traditions in the history of the sciences. And each one of them promotes their own epistemology. Galileo being a particularly important "ancestor", the struggles often lit up violently. Therefore, depending on the case, Galileo becomes a Platonist, a Kantian, an experimentalist, a positivist [...]. (Thuillier 1988, 193, 2040)

Concluding Remarks

We have shown how, before Kuhn's reappraisal and popularization, the concept of Scientific revolution had its contemporary origins in a cluster of debates concerning both a) the philosophical problem of the degree of continuity (or discontinuity) retraceable in the historical development of knowledge and b) the question of the Platonic character of Galilean science. The first problem had a long history to be sure, but it regained a particular urgency at the end of the XIX century. It was also one of the main points of the philosophical agenda of the Neo-Kantian school of Marburg, where Paul Natorp put forth (arguably for the first time) the Galileo's Platonism thesis. In this context, Ernst Cassirer resumed this idea and he gave it a pivotal role in most of his works in the history of science, notably *The Problem of Knowledge* and *The Individual and the Cosmos in Renaissance Philosophy*. It is well known that the GP thesis would have been hardly criticized in the second part of the XX century. But during the Twenties and the Thirties, a time when the history of science as a discipline was still in its early phase of professionalization and institutionalization, the revolutionary role of Galileo at the origins of modern science became one of the main topics of discussion. The GP thesis was then reappraised and developed by important scholars in this field (such as Edwin Arthur Burt and Leo Olschki), but it was especially Alexandre Koyré who gave it its final and most known form linking this concept with the idea of Scientific revolution in his *Galilean Studies* – a book which eventually became the founding text in the history of science after the Second World War.

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