

THE 'PIERRE DUHEM THESIS.'

A REAPPRAISAL OF DUHEM'S DISCOVERY OF THE PHYSICS OF THE MIDDLE AGES

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ABSTRACT: Pierre Duhem is the discoverer of the physics of the Middle Ages. The discovery that there existed a physics of the Middle Ages was a surprise primarily for Duhem himself. This discovery completely changed the way he saw the evolution of physics, bringing him to formulate a complex argument for the growth and continuity of scientific knowledge, which I call the 'Pierre Duhem Thesis' (not to be confused either with what Roger Ariew called the 'true Duhem thesis' as opposed to the Quine-Duhem thesis, which he persuasively argued is not Duhem's, or with the famous 'Quine-Duhem Thesis' itself). The 'Pierre Duhem Thesis' consists of five sub-theses (some transcendental in nature, some other causal, factual, or descriptive), which are not independent, as they do not work separately (but only as a system) and do not relate to reality separately (but only simultaneously). The famous and disputed 'continuity thesis' is part, as a sub-thesis, from this larger argument. I argue that the 'Pierre Duhem Thesis' wraps up all of Duhem's discoveries in the history of science and as a whole represents his main contribution to the historiography of science. The 'Pierre Duhem Thesis' is the central argument of Pierre Duhem's work as historian of science.

KEYWORDS: Pierre Duhem, physics of the Middle Ages, scientific knowledge, history of science

1.

The discoverer of the physics of the Middle Ages was Pierre Duhem (1861-1916) – physicist, philosopher, and historian of science.¹ Since this wondrous episode is rarely mentioned, and the importance of the physics of the Middle Ages to the

¹ Stanley L. Jaki, *Uneasy Genius: The Life and Work of Pierre Duhem* (The Hague/Boston/Lancaster: Martinus Nijhoff Publishers, 1984); Stanley L. Jaki, *Pierre Duhem. Homme de science et de foi*, trans. François Raymondaud (Paris: Beauchesne, 1990); Stanley L. Jaki, "Science and Censorship: Hélène Duhem and the Publication of the 'Système du Monde,'" *The Intercollegiate Review* (Winter 1985-86): 41-49, reprinted in Stanley L. Jaki, *The Absolute beneath the Relative and Other Essays* (New York: University Press of America, 1988), 173-187. For a critical assessment of Duhem's discoveries regarding the physics of the Middle Ages, see John E. Murdoch, "Pierre Duhem and the History of Late Medieval Science and Philosophy in the Latin West," in *Gli studi di filosofia medievale fra otto e novecento. Contributo a un bilancio storiografico. Atti del convegno internazionale Roma, 21-23 settembre 1989*, eds. Ruedi Imbach and Alfonso Maierù (Roma: Edizioni di Storia e Letteratura, 1991), 255-302.

birth of modern science of nature is frequently denied, often ignored, and almost always disregarded, I will first try to sketch briefly the history of this discovery.

That the Middle Ages was a scientifically fertile era was a fact nobody remembered anymore at the beginning of the 20th century. On the contrary, all the *authoritative* people were anchored in the belief that, in what regarded physics, between Archimedes and Galileo there had passed 18 centuries of darkness. This 'knowledge' (actually, a pre-judgment) had imperceptibly become *opinio communis* throughout the cultivated Europe. But, considered in its origin, this 'consensus of authorities' was merely the consequence imposed by the Renaissance position. The Renaissance humanists did not see in the logicism and mathematicism of the great doctors of scholasticism anything else than the corruption of Latin. The division of history into three eras (Antiquity, Middle Ages and the Modern Times) dates from the early Renaissance. This division was made to mark the distance of those claiming it from what immediately preceded them, as well as their adherence to the distant past. According to these value judgments, classical antiquity was associated with bright light, the period that followed it became the 'Dark Ages,' and the age of those who invented this temporal tripartition was presented as an exit out of the night, an awakening, a Renaissance.² An example is Pierre de la Ramée who, in the first three books of his work *Scholarum mathematicarum libri unus et triginta* (1596), presents a detailed account of the development of mathematics in which medieval contributions are completely absent. Was that because there have not existed any? We know well today that they existed. Medieval contributions were absent because they *had* to be ignored: the logic of the tripartite scheme demanded that. Therefore, from the Greek antiquity, Pierre de la Ramée passes directly to the time when, according to him, there took place the 'rebirth of sciences.'³

With his incomparable propagandistic and polemic genius, Voltaire imposed the preconception that traditional Christian institutions exerted a major obscurantist influence on human progress,⁴ while William Whewell, with the

² On this division, see Matei Călinescu, *Five Faces of Modernity: Modernism, Avant-garde, Decadence, Kitsch, Postmodernism* (Durham: Duke University Press, 1987), 19-22.

³ Matthias Schramm, "Steps Towards the Idea of Function: A Comparison between Eastern and Western Science of the Middle Ages: Augustine to Galileo," *History of Science* 4 (1965): 70. For a nuanced discussion of this statement, regarding the contributions to optics which Pierre de la Ramée has himself recommended for publication (the Latin version of Ibn al-Haytham's *Optics* and the compilation of Witelo), see Schramm, "Steps Towards the Idea of Function," 97-98 (note 5).

⁴ David S. Lux, "Societies, Circles, Academies, and Organizations: A Historiographic Essay on Seventeenth-Century Science," in *Revolution and Continuity: Essays in the History and*

authority of the expert, denied the possibility of any form of science in the 'Dark Ages' dominated by the Church, arguing that all the speculations of medieval scholars regarding nature were confused and based on fictitious notions, that natural science is an invention of the 17th century, and its only antecedents can be identified in Antiquity.⁵ In 1788, with the supreme authority given by the most important treatise of mechanics of the century – *Mécanique Analytique* –, the great Lagrange asserted that between Archimedes and Galileo science has experienced eighteen centuries of darkness: "l'intervalle qui a séparé ces deux grands génies disparaît dans l'histoire de la Mécanique."⁶

Five years later, the Marquis de Condorcet confirmed the verdict of the eighteen centuries, and even added them two more. For the revolutionary Condorcet, who wrote *Esquisse d'un tableau des progrès de l'esprit humain* fleeing from Jacobin authorities who sought to arrest him, „the triumph of Christianity marked the entrance into a complete decay of philosophy and sciences,” so that between Plato and the 17th century there have passed twenty centuries of „complete unfruitfulness” for the advancement of science:

Le matelot, qu'une exacte observation de la longitude préserve du naufrage, doit sa vie à une théorie qui, par une chaîne de vérités, remonte à des découvertes faites dans l'école de Platon, et ensevelis pendant vingt siècles dans une entière inutilité.⁷

2.

This was also Duhem's opinion until 1903. As a historian of science, Duhem wholeheartedly embraced the idea (taken in his specialty, apart from Lagrange, also from Dühring⁸ and Mach⁹) that the medieval period was scientifically sterile and that, therefore, between the science of the Greeks (such as it was) and the

Philosophy of Early Modern Science, eds. Peter Barker and Roger Ariew (Washington, D.C.: The Catholic University of America Press, 1991), 25 (note 6).

⁵ William Whewell, *History of the Inductive Sciences from the earliest to the Present Times*, vol. 1 (London: John W. Parker; Cambridge: J. and J.J. Deighton, 1837), 235-236.

⁶ J.-L. Lagrange, *Mécanique analytique*, tome II, 3^e éd., ed. M. J. Bertrand (Paris: Mallet-Bachelier, Gendre et Successeur de Bachelier, 1853), 243

⁷ Marquis de Condorcet, *Esquisse d'un tableau des progrès de l'esprit humain* [first published in 1795], in *Les sciences historiques de l'antiquité à nos jours*, eds. Charles-Olivier Carbonell and Jean Walch (Paris: Larousse, 1994), 107..

⁸ Eugen Dühring, *Kritische Geschichte der allgemeinen Principien der Mechanik* (Berlin: Theobald Grieben, 1873).

⁹ Ernst Mach, *Die Mechanik in ihrer Entwicklung historisch-kritisch dargestellt* (Leipzig: F.A. Brockhaus, 1883).

17th century (when modern science was born, almost *ex nihilo*) we are dealing with a profound discontinuity.¹⁰ For example, in his first article on the history of physics, “Les Théories de l’Optique” (1894), Duhem states plainly that the birth of the discipline he is studying takes place in the 17th century, with Descartes as a source of the optical theories.¹¹ His argument runs as it follows: except for astronomy, hydrostatics and the general principles of statics, the history of natural science in Antiquity and the Middle Ages only gives us „inconsistent or poorly observed facts;” and the truths glimpsed by men of genius are ignored by their immediate descendants. In conclusion, Duhem says in 1894, “the scientist will not find [at the Egyptians and the Greeks] a continuous evolution and a logical concatenation of the professed doctrines;” or, as in the history of science it is only this continuous and logical concatenation that interests us, one cannot speak about a history of physics prior to the 17th century.

After having given in the first four months of 1903 a detailed study on the evolution of mechanics (*L'évolution de la Mécanique*), in which he faithfully follows the conception of all *informed* men of the time, namely that between Aristotle's unusable science and the geometricians of the 17th century, when “sciences are reborn,” there is only the ‘old scholasticism,’ in its turn unusable,¹² Duhem begins to publish in quarterly series in the *Revue des questions scientifiques*, starting with October, a long study on the origins of statics. Bound together, these installments will become after two years the book *Les Origines de la Statique* (2 volumes, 1905; 1906).¹³ The installments had to appear regularly – in January, April, July and October of each year.

For Duhem, at that time already an experienced historian of science, the subject under study did not present any particular problems. Everything was predictable. Counting on Duhem's proverbial conscientiousness, the editor expected an unabated delivery. The first installment appears in the October 1903 issue, where Duhem writes that

¹⁰ R. N. D. Martin, “Duhem and the Origins of Statics: Ramifications of the Crisis of 1903-04,” *Synthese* 83, 3 (1990): 342.

¹¹ Pierre Duhem, “Les Théories de l’Optique,” *Revue des deux mondes* CXXIII (1894): 94-125.

¹² Pierre Duhem, *L'évolution de la mécanique* (Paris: Librairie Scientifique A. Hermann, 1905), 13; *L'évolution de la mécanique* consists of articles published between January 30 and April 30, 1903, in the *Revue générale des Sciences*. After a very general overview of the ‘peripatetician mechanics’ (Chap. I), in which Duhem illustrates the manner of explanation of natural phenomena in Aristotelian physics, the second chapter begins abruptly with this statement: „La renaissance des sciences au début du XVII^e siècle fut une réaction violente contre des semblables explications.”

¹³ Pierre Duhem, *Les Origines de la Statique* (Paris: Librairie Scientifique Hermann, 1905-1906).

Les commentaires des Scolastiques touchant les Méchanika Problémata d'Aristote n'ajoutèrent rien d'essentiel aux idées du Stagirite; pour voir ces idées pousser de nouveaux surgeons et donner de nouveaux fruits, il nous faut attendre le début du XVI^e siècle.¹⁴

The first four chapters of the first volume (all published in the October 1903 installment) pass from Aristotle to Leonardo and Cardan, without the Middle Ages being even mentioned. But for the January issue – surprise! – Duhem does not send the following chapters. He apologized to Father Julien Thirion, his editor, saying that there have appeared a number of supplementary readings which he had not taken into account in the original plan of the work.¹⁵ Chapter 5, which appears in the *Revue des questions scientifiques* in the April 1904 issue and which should have continued with the contributions in statics after Cardan (16th century), makes a sudden return (back until the 13th century). Perfectly illogical to the original plan, which did not even mention the contributions of the Middle Ages to the science of statics, Duhem informs us that, before studying 'the fundamental treatise of Statics' produced by the 'enigmatic' Jordanus Nemorarius, there should be collected the 'debris' on this subject, scattered throughout the manuscripts left by the school of Alexandria.¹⁶ Chapters 5-9 are studying what the Alexandrians have received from the school of Nemorarius, subsequently detailing the contributions of this school to the development of statics. Only Chapter 10 resumes the line interrupted at the end of Volume I, i.e. in the middle of the 16th century, with Guido Ubaldi and Benedetti. Tartaglia's name, which now appears for the first time (as expressly stated in the preface to Volume I, from 21 March 1905, written *after* the discovery of the statics of the Middle Ages), referred to as a plagiarist of Nemorarius, is mentioned for the merit of having broadcast in the middle of the 16th century some contributions of the 13th which otherwise would have remained completely ignored.

In conclusion, although the reference to Nemorarius was not unknown to some historians of the Middle Ages,¹⁷ Duhem was the only historian of science to

¹⁴ Duhem, *Les Origines de la Statique I*, 13.

¹⁵ R. N. D. Martin, "The Genesis of a Mediaeval Historian: Pierre Duhem and the Origins of Statics," *Annals of Science* XXXIII (1976): 121.

¹⁶ Duhem, *Les Origines de la Statique I*, 62.

¹⁷ Even though Jordanus Nemorarius remains unknown to the historians of physics (to Lagrange, to Mach, to Wohlwill), the historians of mathematics do mention him: Montucla and Chasles (*cf.* Martin, "The Genesis of a Mediaeval Historian," 123; Anastasios Brenner, Duhem: *Science, réalité et apparence. La relation entre philosophie et histoire dans l'oeuvre de Pierre Duhem* (Paris: Vrin, 1990), 145, note 3). Moreover, Bosmans knew the two treatises *De ponderibus* in question and anticipated that Duhem would come upon them (see Jaki, *Uneasy Genius*, 385), all

follow the thread of quotes on this author – referring to the original manuscripts and revealing texts which everyone had forgotten (but which the ‘inventors’ of modern science in the 17th century still knew very well) –, the only one who knew how to historically and epistemologically evaluate the things he had discovered. The result of this work was the discovery of the vast medieval discussions about the principle of virtual velocities,¹⁸ with which the great sunken continent of medieval physics began to regain the attention of scholars: first by the discovery that the principle of virtual velocities had also been known to the medieval scholars, as a principle of the demonstration of the static equilibria, and then by other findings, suggesting that the scholasticism of the 14th century had developed a dynamics completely different from the Aristotelian one. This extraordinary event – the beginning of the discovery of the physics of the Middle Ages – can be located between the summer and winter of 1903 (as the reference to Tartaglia appears only in the April 1904 installment).¹⁹

The discovery of the physics of the Middle Ages was a surprise *first of all* for Duhem. He did not make this discovery because he was Catholic (as it was said, trying to reduce his discovery to an apologetic enterprise),²⁰ but because, against

the discussion with Father Thirion, sometime after October 1903, which Bosmans remembers in the evocation of Duhem (Henri S.J. Bosmans, “Pierre Duhem: Notice sur ses travaux relatifs à l’histoire des sciences,” *Revue des questions scientifiques* 80, 30 (1921): 41).

¹⁸ Stanley L. Jaki, “Foreword,” in Pierre Duhem, *Medieval Cosmology. Theories of Infinity, Place, Time, Void, and the Plurality of Worlds*, ed. and trans. Roger Ariew (Chicago and London: The University of Chicago Press, 1985), xv.

¹⁹ Martin dates the great discovery at the end of the autumn of 1903 (Martin, “The Genesis of a Mediaeval Historian,” 120).

²⁰ See, for example, Guy Beaujouan, „Alexandre Koyré, l’évêque Tempier et les censures de 1277,” in *Science: The Renaissance of a History: Proceedings of the International Conference Alexandre Koyré, Paris, Collège de France, 10-14 June 1986*, ed. Pietro Redondi, *History and Technology* 4, Special Issue (1987): 425:

Vous savez tous comment, du fait de sa propre carrière scientifique et de son catholicisme militant, Pierre Duhem était idéologiquement conditionné à vouloir chercher dans la scolastique chrétienne les antécédents préparant l’éclosion de la science moderne du XVII^e siècle.

Beaujouan's statement is *factually* false, as demonstrated in R.N.D. Martin, *Pierre Duhem. Philosophy and History in the Work of a Believing Physicist* (Chicago and La Salle, Illinois: Open Court, 1991), *passim*. As shown in the famous letter to Father Bulliot dated May 21, 1911, Duhem does not make apologetics with his discoveries: he asks the Catholics to understand that the *facts* he discovered prove that the anti-Catholic and anti-Christian theses regarding the Middle Ages are false, *factually* false (the text of the letter may be found in Hélène Pierre-Duhem, *Un Savant Français: Pierre Duhem* (Paris: Librairie Plon, 1936), 158-169); closer to our

his first convictions regarding the scientific nullity of the Middle Ages, Duhem behaved like a true conscientious and honest scientist: faced with the existence of new facts, he has granted them priority to his preconceptions and revised his initial theories.²¹ His remaining life (1903 to 1916) was dedicated by Duhem to the deepening of this epochal discoveries. There have resulted out of this concern two monumental works: *Études sur Léonard de Vinci* (3 volumes, 1906, 1909, 1913) and *Le Système du Monde. Histoire des doctrines cosmologiques de Platon à Copernic* (10 volumes, 1913, 1914, 1915, 1916, 1917, 1954, 1956, 1958, 1959). *Le système du monde* should have had twelve volumes and a summary of three hundred pages, which to synthetically rebuild the argument of the entire series. The last two volumes and the summary have not been written, and the tenth volume remained unfinished. Duhem died suddenly of a heart attack on September 14, 1916. He was only 55 years old.

The studies on Leonardo da Vinci were occasioned by the publication of his notebooks and are devoted to the assessment of his scientific thought's sources, as well as of the impact his theories had on the development of the modern science of nature. The first two volumes bear the subtitle *Ceux qu'il a lus et ceux qui l'ont lu* (written between 1905-1906 and 1907-1908, respectively), while the third and most voluminous (written between 1909-1912) is subtitled "Les précurseurs parisiens de Galilée" and is preceded by a preface which has the force of a manifesto:

La science mécanique inaugurée par Galilée, par ses émules, par ses disciples, les Baliani, les Torricelli, les Descartes, les Beeckman, les Gassendi, n'est pas une création; l'intelligence moderne ne l'a pas produite de prime saut et de toutes pièces dès que la lecture d'Archimède lui eut révélé l'art d'appliquer la Géométrie aux effets naturels. L'habileté mathématique acquise dans le commerce des géomètres de l'Antiquité, Galilée et ses contemporains en ont usé pour préciser et développer une Science mécanique dont le Moyen-Âge chrétien avait posé les principes et formulé les propositions les plus essentielles. Cette Mécanique, les

times, it has been reproduced in Jaki, *Pierre Duhem*, 235-239 (Nr. 15: "Deux chaires catholiques pour les sciences").

²¹ As a faithful of the Roman Catholic Church, perhaps Duhem would have liked to believe that the church has stimulated the free research, but before the *annus mirabilis* 1903 he did not have evidence that this would have happened. Therefore, as a good scientist, he allowed the Christian in himself only the exercise of faith, accepting as *factum* only what historical knowledge allowed him to accept as philosophical truth. Thus, he stated in his studies prior to the discovery of the physics of the Middle Ages exactly the opposite of what he would have perhaps liked to believe, namely that the period of maximum social development of Christianity was also an era of total scientific sterility. Therefore the discovery of the physics of the Middle Ages was not an apologist's work.

physiciens qui enseignaient, au XIV^e siècle, à l'Université de Paris l'avaient substitué à la Dynamique d'Aristote [...]. Au temps de la Renaissance, l'archaïsme superstitieux, où se complaisaient également le bel esprit des Humanistes et la routine averroïste d'une Scolastique rétrograde, repoussa cette doctrine des 'Modernes.' [...] Mais à la suite des condamnations portées, en 1277, par l'évêque de Paris, Étienne Tempier, contre une foule de thèses que soutenaient 'Aristote et ceux de sa suite,' voici qu'un grand nombre se dessine, qui va libérer la pensée chrétienne du joug du Péripatétisme et du Néoplatonisme, et produire ce que l'archaïsme de la Renaissance appellera la Science des 'Modernes.' [...] Cette Mécanique, à la fois céleste et terrestre, à laquelle Newton devait donner la forme que nous admirons aujourd'hui, la voici, d'ailleurs, qui, dès le XIV^e siècle, tente de se constituer. [...] Cette substitution de la Physique moderne à la Physique d'Aristote a résulté d'un effort de longue durée et d'extraordinaire puissance. [...] Jusqu'à ces dernières années, la Science du Moyen-Âge était tenue pour inexistante.²²

When he was writing these lines, on the 24th of May 1913, the first volume of *Le Système du Monde* had already appeared, and the next four volumes were probably already drafted²³. This history of cosmological doctrines from Plato to Copernicus, the crowning and final mark of the discovery from the autumn of 1903, was designed to completely change the fate of specialized historical scholarship, creating a new academic discipline and setting in a sustainable and authoritative manner its further developmental milestones.²⁴ In these volumes

²² Pierre Duhem, *Études sur Léonard de Vinci. Les précurseurs parisiens de Galilée*, troisième série, 1913. (Montreux: éditions des archives contemporaines, 1984), v, vii, x, xiii.

²³ Martin, *Pierre Duhem*, 10.

²⁴ John E. Murdoch, a very severe critic of Duhem's thesis, acknowledges in the conclusion of an article dedicated to his contribution to the history of medieval science that

Duhem has to a great extent set the topics for subsequent historians of late medieval science. Not only have earlier investigators, like Dijksterhuis and Michalski, followed Duhem's scenario, but the same has been true to a large extent in the case of others who have addressed the history of fourteenth-century science in general, such as Maier and Clagett. Duhem's influence in this regard is, moreover, no less evident among historians of medieval philosophy than among historians of medieval science. [...] In conclusion, then, when Dana Durand claimed that all future historians would spend most of their time 'working intensively the veins' Duhem had opened, he did not sufficiently appreciate that the lode ran well beyond the history of medieval science and penetrated well into the terrain of late medieval philosophy. And all that in spite of the continued successful criticism of the yield Duhem had derived from it.

there are comprised in their most elaborate form all the findings and interpretations which, put together, we could call the 'Pierre Duhem Thesis.'²⁵ I claim that there is an argument which encompasses all of Pierre Duhem's discoveries regarding the history of science and that this argument can be synthesized as a combination of several principles, sentences and conjectures forming a whole which I call the 'Pierre Duhem Thesis.'

3.

What is, then, the 'Pierre Duhem Thesis'? Most generally, the 'Pierre Duhem Thesis' states that the Latin Middle Ages had a significant and important (even decisive) contribution to the gradual progress of science, from Antiquity until the 17th century. Analyzed in its particular statements, the 'Pierre Duhem Thesis' can be summed up by stating several sub-theses:

(i) The sub-thesis 'The Theological Revolution.'²⁶ In the preface to the third part of *Le Système du monde*, significantly entitled "Le péripatétisme, les religions et la science d'observation,"²⁷ Duhem advances the argument that Greek science was prevented from developing and evolving beyond a certain threshold (where it was blockaded) by its philosophical and religious premises, which were neo-platonic and 'astro-biological' (the divine nature of stars, the animation of matter,

(Murdoch, "Pierre Duhem and the History of Late Medieval Science," 299; 301-302). See also Dana B. Durand, "Nicole Oresme and the Medieval Origins of Modern Science," *Speculum* 16, 2 (1941): 167-185.

²⁵ What I call here the 'Duhem Thesis' has nothing to do with the 'Quine-Duhem thesis' (sometimes called the 'Duhem-Quine thesis,' the 'Duhem thesis,' or the 'D-Thesis'); the 'Duhem Thesis' I refer to is deduced directly from his writings and is not assigned to him *par méprise*, such as the 'Quine-Duhem thesis,' which, as demonstrated by Robert Ariew, is *not* related with what Duhem himself advocated (*cf.* Roger Ariew, "The Duhem Thesis," *British Journal of the Philosophy of Science* 35 (1984): 313-325).

²⁶ Curiously enough, the notion of the 'Theological Revolution,' although central in Duhem's argument, has never been analyzed in the specialized literature.

²⁷ The subject is treated in Pierre Duhem, *Le Système du Monde. Histoire des doctrines cosmologiques de Platon à Copernic*, tome IV, 1916, Nouveau tirage (Paris: Hermann, 1973), 309-320 ("La crue de l'aristotélisme," "Avant-propos," "Le péripatétisme, les religions et la science d'observation"). Anastasios Brenner underlines the importance of this section by fully reproducing it in Pierre Duhem, *L'aube du savoir. Épitomé du Système du Monde. Histoire des doctrines cosmologiques de Platon à Copernic*, ed. Anastasios Brenner (Paris: Hermann, Éditeurs des sciences et des arts, 1997), 225-236 (with a small omission: compare Duhem, *Le Système du Monde IV*, 314 to Duhem, *L'aube du savoir*, 230).

etc.).²⁸ This blockage could only be overcome by ensuring a ‘theological revolution’ as a precondition for the adoption of the Copernican theory; through the ‘theological revolution’ applied to the mind, the scientific mind was freed from the ontological premises of Neoplatonism and astrobiology, which allowed its opening to an ontological perspective compatible with the data of existence of the modern science of nature.²⁹

A similar argument is to be found in the second part of *Le Système du Monde*, which is entitled “L’Astronomie latine au Moyen Âge” and begins with a section called “Les Pères de l’Église et la science profane.”³⁰ Duhem brings into attention that, although it is not possible to find in the works of the Church Fathers scientific contributions comparable to those of the Greek science, their views should not be ignored because

their teachings in Physics and Astronomy are the primal germs out of which medieval Christian cosmology will slowly and gradually develop.³¹

The Church Fathers attacked from the perspective of Christian theology the principles of Greek science which happened to be exactly those which, according to Paul Tannery,³² contributed the most to stop the progress of ancient science and exhausted its fertility: the principle of the eternity of prime matter, the faith in the domination of stars over sublunary life, and the temporal cyclicity of the world. Duhem's conclusion is:

En ruinant, par ses attaques, les Cosmologies du Péripatétisme, du Stoïcisme et du Néo-Platonisme, les Pères de l’Église font place nette à la Science moderne.³³

And here, even though he does not explicitly use the formula of ‘theological revolution,’ one still basically speaks of a ‘theological revolution,’ understood by Duhem, like in the first case, as a prior mental framework able to make possible ‘the reason of the believer’³⁴ – that is, the reason which, thus *positioned*, could modern-physically think of nature.

²⁸ The term ‘astrobiology’ was coined by René Berthelot, *La pensée de l’Asie et l’astrobiologie* (Paris: Payot, 1938).

²⁹ Duhem, *Le Système du Monde IV*, 316-317.

³⁰ Pierre Duhem, *Le Système du Monde. Histoire des doctrines cosmologiques de Platon à Copernic*, tome II, 1914, Nouveau tirage (Paris: Hermann, 1984), 392-408; Duhem, *L’aube du savoir*, 125-138.

³¹ Duhem, *Le Système du Monde II*, 407-408; Duhem, *L’aube du savoir*, 138.

³² Paul Tannery, *Recherches sur l’histoire de l’Astronomie ancienne* (Paris: Gauthier-Villars & Fils, 1983), 280-281.

³³ Duhem, *Le Système du Monde II*, 408; Duhem, *L’aube du savoir*, 138.

³⁴ Duhem, *Le Système du Monde II*, 315; Duhem, *L’aube du savoir*, 231.

(ii) The sub-thesis 'The Condemnation of 1277.' Although medieval Aristotelianism was important for the maturation and professionalization of reflection in natural philosophy, the release from its philosophical premises was the second fundamental precondition for the further development of science beyond the achievements of ancient science. The second precondition was realized by what we could conventionally call 'the Condemnation of 1277,' by which the medieval mind was compelled by the exigencies of the Christian faith to think the natural world starting not from the Greek (Aristotelian) necessitarianism, as did the 13th-century scholasticism, but from the absolute power of God (*potentia Dei absoluta*). The spirit of the Condemnation is illustrated by Article 147, which condemns the opinion that it is impossible for God something suitable for nature (where the impossible did not designate the logical impossible, which was accepted, but the natural one, which was rejected). This mode of vision removed the Aristotelian obstacles in the conception of nature and in the discourse about it (it was only thus that one could admit the plurality of worlds and the existence of vacuum, which nature such as Aristotelianism understood it rejected as impossible), and favored the thought regarding the counterfactuals by the appearance and generalization of the ratiocination by 'thought experiments' (*Gedankenexperimente*).³⁵ For this reason, according with Duhem, the Condemnation of 1277 are one of the possible points that might date the 'birth' of the modern science of nature.³⁶

(iii) The sub-thesis 'The Continuity.' After having discovered the statics of the Middle Ages (*annus mirabilis* 1903), Duhem has become convinced that not only the selection of the hypotheses on which physical theory is built is subjected to a principle of continuity (1893),³⁷ but also the history of science follows this principle, according to the historical observation that science progresses gradually and continuously, without rupture or revolution:

³⁵ Edward Grant, „The Effect of the Condemnation of 1277,” in *The Cambridge History of Later Medieval Philosophy. From the Rediscovery of Aristotle to the Desintegration of Scholasticism 1100-1600*, eds. Norman Kretzmann, Antony Kenny, and Jan Pinborg (Cambridge: Cambridge University Press, 1984), 537-539.

³⁶ Pierre Duhem, *Études sur Léonard de Vinci. Ceux qu'il a lus et ceux qui l'ont lu*, deuxième série, 1909 (Montreux: éditions des archives contemporaines, 1984), 408-423; Duhem, *Études sur Léonard de Vinci. Les précurseurs parisiens de Galilée*, vii; the complete discussion of the Condemnation's consequences is in Pierre Duhem, *Le Système du Monde. Histoire des doctrines cosmologiques de Platon à Copernic*, tome VI, Nouveau tirage (Paris: Hermann, 1984), *passim*.

³⁷ Pierre Duhem, "L'école anglaise et les théories physiques," *Revue des Questions Scientifiques* 34 (1983): 345-378. Reprinted in Pierre Duhem, *Prémices philosophiques*, ed. Stanley L. Jaki (Leiden, New York etc.: E.J. Brill, 1987), 113-146.

La science mécanique et physique dont s'enorgueillissent à bon droit les temps modernes découle, par une suite ininterrompue de perfectionnements à peine sensibles, des doctrines professées au sein des écoles du moyen âge ; les prétendues révolutions intellectuelles n'ont été, le plus souvent, que des évolutions lentes et longuement préparées ; les soi-disant renaissances que des réactions fréquemment injustes et stériles ; le respect de la tradition est une condition essentielle du progrès scientifique.³⁸

The sub-thesis of the continuity has therefore a double aspect: an epistemological one, when it is applied to science; a historical one, when it is applied to the history of science.

(iv) The sub-thesis 'Galileo's forerunners of the 14th century' (or 'Duhem's canonical list'). Within the overall framework of the thesis of continuity, Duhem argues the exceptional importance of the contributions belonging to the scholastics of the 14th century, primarily those who taught at the University of Paris (Jean Buridan, Nicole Oresme, Albert de Saxe, Thémom Judaeus, Marsilius de Inghen), and then of those who were associated with Merton College, Oxford (Thomas Bradwardine, Roger Swineshead, William Heytesbury, Richard Kilvington, John Dumbleton).³⁹ These contributions form 'Duhem's canonical list' (or, as John E. Murdoch named it, 'Duhem's canonized roster of fourteenth-century accomplishments').⁴⁰ The scientific achievements of the 14th century, which

³⁸ Duhem, *Les Origines de la Statique I*, iv (the Preface is dated March 21, 1905).

³⁹ The different appraisals of the two schools, the Paris and the Oxonian ones, have two explanations: firstly, a sort of anti-English preconception and a French nationalism, argued by the taste for the elegant ratiocination (*l'esprit de finesse*) and the repulsion for (the excess of) logicism; secondly, there is an epistemological limit of understanding (see Murdoch, "Pierre Duhem and the History of Late Medieval Science," 262-270): according to Murdoch, Duhem did not understand the exceptional epistemological value of the 'sophismata' exercises, which he treated as "cette acrobatie logique [qui] était le *sport* en vogue à l'École d'Oxford" (Pierre Duhem, *Le Système du Monde. Histoire des doctrines cosmologiques de Platon à Copernic*, tome VII (Paris: Hermann, 1956), 619): the type of ratiocination developed and refined in order to solve the *sophismata*, named by Murdoch '*secundum imaginationem* reasoning,' was in his opinion the fundamental scientific novelty of the 14th century, a fact completely unnoticed by Duhem (Murdoch, 291-292). Murdoch quotes two important authors to support his point of view (Murdoch, 294, note 192): „Man möchte beinahe sagen: Bradwardine wollte die Principia mathematica philosophiae naturalis seines Jahrhunderts schreiben" (Anneliese Maier, *Die Vorläufer Galileis im 14. Jahrhundert. Studien zur Naturphilosophie der Spätscholastik*, Band I (Roma: Edizioni di Storia e Letteratura, 1949), 86, note 10); „[Bradwardine's *Tractatus de proportionibus*] should be seen as at least a partial attempt to create a new mathematical science of motion" (Andrew George Molland, „Medieval Ideas of Scientific Progress," *Journal of History of Ideas* 39 (1978): 572).

⁴⁰ Murdoch, "Pierre Duhem and the History of Late Medieval Science," 258.

according to Duhem show the debt of Galileo and Descartes to the physics of the Middle Ages, would run as it follows (I pursue the list established by Murdoch): the correct explanation of the reason for which the motion of a projectile continues after he is not moved by an agent; the correct explanation of the uniformly accelerated motion in free fall; the development of the theory regarding the 'latitude of forms;' the postulation of the possibility of existence of infinite and infinitesimal quantities, of space vacuum, of the rotation of the earth, and of the plurality of worlds; the crystallization of new and clear concepts of motion, place and time, which were non-Aristotelian.

(v) The sub-thesis 'The Domingo de Soto connection.' Duhem discovered, in a treatise on Aristotle's physics written by Domingo de Soto and published in 1545, that in the scholastic tradition to which the author pertained the following theorems were well known: the free fall of bodies is a motion accelerated with respect to time; the motion of a body thrown vertically upwards is uniformly slowed; in order to calculate the space covered in both movements, one must apply the demonstrations developed by Nicole Oresme for the *uniformiter difformis* movement (or, which is the same thing, the mean speed theorem developed by the Mertonians).⁴¹ "Ces lois, d'ailleurs," says Duhem,

il n'en revendique pas l'invention; bien plutôt, il semble les donner comme vérités communément reçues; sans doute, elles étaient couramment admises par les maîtres dont, à Paris, Soto a suivi les leçons. Ainsi, de Guillaume d'Ockam à Dominique Soto, voyons-nous les physiciens de l'École parisienne poser tous les fondements de la Mécanique que développeront Galilée, ses contemporains et ses disciples.⁴²

Historiography took on this thesis of Duhem under the form of two research programs designed to solve the 'two de Soto enigmas.' Koyré is the first who, in an article in the late 50s, referred to this Duhem thesis as the 'enigma of Domingo de Soto.' Here we have it in his wording:

[h]ow did [Domingo de] Soto arrive to give the movement of falling as an example of uniformly accelerated motion and even to describe as something self-understood this transposition of a purely mathematical conception into physical reality, although the mathematicians and logicians of the schools in Paris and Oxford have not realized this transposition?⁴³

⁴¹ Duhem, *Études sur Léonard de Vinci. Les précurseurs parisiens de Galilée*, 555-562. Duhem only refers to Oresme (561) and mentions Bradwardine in passing (557).

⁴² Duhem, *Études sur Léonard de Vinci. Les précurseurs parisiens de Galilée*, xi.

⁴³ Alexandre Koyré, "Fizica," in *Istoria generală a științei*, vol. II, ed. René Taton (București: Editura Științifică, 1971), 106. Koyré's question departs from the assumption that Soto, while

The second 'de Soto enigma' is whether and how Galileo came to know Domingo de Soto's theorems (Duhem's conjecture being that the missing link between Galileo and the 14th-century physics is Domingo de Soto).⁴⁴ The answer to the second enigma and the acceptance of the truth of the three theorems attributed by Duhem to Domingo de Soto represent the 'Domingo de Soto connection.'

4.

While contemplating the nature of the five special sub-theses which compose together the general 'Duhem Thesis,' two implicit observations emerge.

The first observation is that, in relation to what we now call "the birth of the modern science of nature in the 17th century," sub-theses (i) and (ii) are of one type, while sub-theses (iv) and (v) are of another. The former have the structure of transcendental reasoning, which has the form: "in order for 'X' to be possible, the $\{y_n\}$ conditions must take place;" the latter have the structure of causal reasoning, having the form: "the existence of 'Y' produces the existence of 'X.'" Neither the 'theological revolution,' nor the 'Condemnation of 1277' do not represent *effective causes* of the emergence of the modern science of nature. We could call them transcendental 'conditionalities,' in order to decidedly distinguish them from the effective causes, which alone are 'causal.' The transcendental 'conditionalities' create the framework which makes possible, under certain conditions, the appearance of something, but do not necessarily or directly actuate its appearance. To make possible does not effectively mean to be a cause, but rather to open a field of possibilities. If this 'field of possibilities' is not opened, the occurrence of the causes which could theoretically be effective remains without effect. The effectiveness of the effective causes is conditioned by the existence of a 'field of possibilities;' and the 'field of possibilities' is opened only by the activation of some transcendental 'conditionalities.'

The second observation is that the two aspects of sub-thesis (iii) ('the thesis of continuity'), the epistemological-methodological and the historical one, are fundamentally inseparable. On the one hand, the thesis of continuity is a

not being 'a great philosopher' and his physics being 'traditional and eclectic,' surprisingly fell on an innovative and correct solution to the problem of falling and vertical projection of bodies; in the same time, Koyré wondered, "how come that from him to Galilei [Sotto's solution] was not adopted by anyone?"

⁴⁴ This second enigma was finally solved by William A. Wallace, who confirmed Duhem entirely (William A. Wallace, "The Enigma of Domingo de Soto: *Uniformiter difformis* and Falling Bodies in Late Medieval Physics," *Isis* 59, 4 (1964): 384-401).

methodological principle of prescriptive nature, deeply rooted in Duhem's conception of physical theory:

The thesis of historical continuity is one part of his epistemology with which Duhem attempts to resolve the problem of the choice of hypotheses.⁴⁵

The methodological principle of continuity saves from mutual incoherence the particular theories of physics and makes them advance in their historical evolution towards a 'natural classification' of things which will reflect the ontological truth of the final theory.⁴⁶ It is exactly the methodological aspect of the thesis of historical continuity that makes Duhem's epistemology to be not conventionalist or instrumentalist, but realistic in a special way ('convergent or motivational realism').⁴⁷

On the other hand, when referring to the history of science, the thesis of continuity has a contingent aspect, as Ariew and Barker noticed:

the thesis is most compelling as a contingent claim about history of science: continuity just happens to be the case; it could have been otherwise.⁴⁸

Indeed, Duhem reached the thesis of 'continuity' *a posteriori*, as a result of the discovery he had made, and not *a priori*, as a result of the identification of a

⁴⁵ Roberto Maiocchi, "Pierre Duhem's *Aim and Structure of Physical Theory*: A Book Against Conventionalism," *Synthese* 83, 3 (1990): 395. Maiocchi's thesis on Duhem was extensively developed in his *Chimica e filosofie. Scienza, epistemologia, storia e religione nell' opera di Piere Duhem* (Firenze: La Nuova Italia Editrice, 1985).

⁴⁶ Duhem, *Prémices philosophiques*, 132-138: at pp. 134-135, Duhem speaks of the fact that the methodological principle of continuity eliminates the incoherence of the theories based on irreconcilable hypotheses; and at pp. 136-138 he speaks of the natural classification and of the perfection of the ideal theory. For natural classification, see also: Pierre Duhem, *La théorie physique: son objet, sa structure. Deuxième édition revue et augmentée* (Paris: Librairie philosophique J. Vrin), 460. In recent literature, Sonia Maria Dion argued that

[t]he association of natural classification to the thesis of historical continuity [is] an essential condition to the possibility of assigning a goal to the evolution of physical theory.

(Sonia Maria Dion, "Pierre Duhem and the Inconsistency Between Instrumentalism and Natural Classification," *Studies in History and Philosophy of Science* 44 (2013): 12–19).

⁴⁷ The phrase 'motivational realism' belongs to Karen Merikangas Darling (Karen Merikangas Darling, "Motivational Realism: The Natural Classification for Pierre Duhem," *Philosophy of Science* 70, 5 (2003): 1125–1136); see also Roger Ariew, "Pierre Duhem," in *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, Fall 2014 Edition. <http://plato.stanford.edu/archives/fall2014/entries/duhem/>, § 2.2.

⁴⁸ Roger Ariew and Peter Barker, "Duhem and Continuity in the History of Science," *Revue internationale de philosophie* 46, 182 (1992): 323.

philosophical principle that lies beyond experience and is independent of it. As such, from a historical perspective, we could say that the thesis of continuity does not function with Duhem as a philosophical or teleological principle, but as a description.

At the same time, we must note that the methodological prescription imposed on particular theories *in epistemology* has necessary consequences on the evolution of theories towards a 'natural classification' (the final theory) *in history*. In fact, the *proper* functioning of epistemology creates a *certain* history and no other. That is why I said that the two aspects of sub-thesis (iii), the epistemological-methodological and the historical ones, are non-separable. And for this reason I think that the real challenge of the thesis of continuity formulated by Duhem is not in its understanding as a historical-contingent statement of the type "it may have also been different, even though it actually happened so" (the Ariew and Barker interpretation cited above), but as a strong statement of the type „it happened so, because it could only happen thus" (the Jaki thesis).⁴⁹ Formulated briefly, the Duhem-Jaki thesis (as Eric V. Snow names it)⁵⁰ argues that "the world view of Christianity was absolutely necessary for the rise of modern science."⁵¹

⁴⁹ The main books in which Stanley L. Jaki dealt with the conditions necessary for the birth of the modern science of nature, analyzing both the situations when science could not appear, although its birth seemed imminent (what he calls 'the 'stillbirth' of science'), as well as the situations when science could appear are: *Science and Creation. From Eternal Cycles to an Oscillating Universe* (Edinburgh: Scottish Academic Press, 1974); *The Road of Science and the Ways to God. The Gifford Lectures 1975 and 1976* (Chicago: University of Chicago Press; Edinburgh: Scottish Academic Press, 1978); *The Origin of Science and the Science of its Origins* (Edinburgh: Scottish Academic Press; South Bend, Ind.: Gateway Editions, 1978); *The Savior of Science* (Washington, D.C.: Regnery Gateway, 1988); *Christ and Science* (Royal Oak, Michigan: Real View Books, 2000).

⁵⁰ Eric V. Snow, „Christianity: A Cause of Modern Science?" *Acts & Facts* 27, 4 (1998). <https://archive.org/details/IsChristianityACauseOfScienceTheDuhem-jakiAndMertonThesesExplained>. Accessed on February 17, 2015.

⁵¹ That does not mean, as François Mentré already warned shortly after the death of Duhem, that science is a 'Christian product:' "Duhem does not say that modern science is a product of Christianity; he rather says that Christianity has been an auxiliary, and an indispensable one, to the scientific development" (François Mentré, "Pierre Duhem: Historien et Philosophe," *Revue des Jeunes* 15 (1917): 139, note). Stanley Jaki, who quotes this warning, wholly approves it: "This is an all-important point, often forgotten in sympathetic portrayals of the role of Christianity in the rise of science" (Jaki, *Uneasy Genius*, 231-232, note 36).

5.

These two observations allow us to more clearly evaluate the complex structure of what I call the 'Pierre Duhem Thesis.' 'The Duhem thesis' is, in my opinion, the central argument of Pierre Duhem's work as historian of science. The 'Pierre Duhem thesis' can not be reduced to any of its sub-theses. The five sub-theses are not independent, they do not work separately and do not relate to reality separately (but only as a system). Their diverse theoretical status (some have a transcendental character, while some other causal, factual, or descriptive ones) makes the way in which they relate each and all together to historical reality to be particularly complex. Therefore, the factual assessment of the sub-theses, as well as the historical judgment on the value of the overall argument advanced by Duhem must, I think, be both balanced and prudent, and the identification of the direct causalities must always be combined with the understanding of the role of transcendental 'conditionalities.'

The distinction between transcendental 'conditionalities' and effective causes is essential to understand the finesse of Duhem's argument. For example, Duhem never claimed that the modern science of nature is due to the Condemnation of 1277.⁵² He referred to the Condemnation as to some transcendental 'conditionalities' which opened for the physics of the 14th century a 'field of possibilities,' just as the 'Theological Revolution' functioned, in relation to the 'astrobiology' of the Greeks, as an inhibitor of ontological representations, opening by these very inhibitions the horizon of some other representations, more capable than their antecessors to make system with principles favorable to the

⁵² This is how Alexandre Koyré chose to read Duhem's statements, and his interpretation became authoritative, *y compris* among the historians of the Middle Ages (even though he was not one): Alexandre Koyré, "Le Vide et l'espace infini au XIV^e siècle," *Archives d'histoire doctrinale et littéraire du Moyen Âge* XVIII (1949), reprinted in Alexandre Koyré, *Études d'histoire de la pensée philosophique* (Paris: Gallimard, 1971), 37-45); for the effect on the historians of the Middle Ages, see the influence of this article on Marshall Clagett: "I was [...] impressed by his beautiful paper "Le Vide et l'espace infini au XIV^e siècle," and particularly by the doubt it cast on the easy generalizations of Pierre Duhem." ("Commemoration," *Isis* 57 (1966), quoted in I. Bernard Cohen, „Alexandre Koyré in America: Some Personal Reminiscences," in *Science: The Renaissance of a History*, ed. Redondi, 60) — Clagett was mainly impressed by the way Koyré amended Duhem! It was precisely this malicious readings, which positively impressed Clagett, that the later historians of the Middle Ages would reveal as historically false (see Beaujouan, "Alexandre Koyré," 425-429; and Edward Grant, "The Condemnation of 1277. God's Absolute Power, and Physical Thought in the Late Middle Ages," *Viator* 10 (1979): 211-244; for an overall assessment, see Edward Grant, *The Foundations of Modern Science in the Middle Ages. Their Religious, Institutional, and Intellectual Contexts* (Cambridge: Cambridge University Press, 1996, 70-126).

development of a mathematical science of nature, overcoming thus the impasse of the Greek science. At the same time, the sub-thesis of continuity must be understood both in its double epistemological-normative and historical-descriptive aspect (see discussion above), as well as in terms of the complex historical causalities: a fine interaction between transcendental ‘conditionalities’ and effective causes.

Given the complexity of the historical argument formulated by Duhem (which I named the ‘Pierre Duhem Thesis’), the legacy of his findings was reportedly extremely complex. Duhem established a number of facts (the physics of the Middle Ages, the “canonical roster” etc.), proposed several causal links (the Domingo de Soto conjecture, implying the Collegio Romano connection etc.), argued some historical ‘conditionalities’ of transcendental type (the Theological Revolution, the Condemnation of 1277), and advanced the great historical hypothesis of continuity (the Parisian precursors of Galileo).

Pierre Duhem's findings were epoch-making. They revealed a sunken and completely forgotten continent (the physics of the Middle Ages), put on the map the topic of the links between the modern and the medieval worlds (which seemed to be resolved by the extremist views of Petrarch in the 14th century and Voltaire in the 18th), restructured completely the contents of the history of science and of the history of medieval philosophy, and gave impetus to a deeper institutional transformation in the teaching of history and philosophy of science. But the fact that the physics of the Middle Ages existed, and that the emergence of the modern science of nature, whatever its relation to it, cannot be imagined without it, has remained what Jean-François Revel called ‘une connaissance inutile.’ By tracing the complex and complicated manner in which this formidable discovery was only partially integrated into the dominant historiography of science, and the failure of our general culture to integrate it one can understand that the reasons of this resistance to the ‘Pierre Duhem Thesis’ are deeply rooted into the moral and philosophical settings of our modern civilization. But this is a story to be told in another article.^{53, 54}

⁵³ See Horia-Roman Patapievici, “The Discovery of the Physics of the Middle Ages by Pierre Duhem. The Fate and Meaning of a Truth,” forthcoming in *Meaning and Truth*, eds. Sorin Costreie and Mircea Dumitru (București: Pro Universitaria, 2015).

⁵⁴ This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU 159/1.5/S/133675.