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THE RELATION BETWEEN HISTORY AND PHILOSOPHY IN DUHEM’S *AIM AND STRUCTURE OF PHYSICAL THEORY*

Anastasios Brenner*

Introduction

In the opening pages of *The Aim and Structure of Physical Theory* Pierre Duhem claimed to provide “a simple logical analysis of the method by which physical theory makes progress”. Yet his book contains a large amount of history. One finds numerous examples taken from the history of physics as well as a general interpretation of progress as a continuous process. History also enables us to go beyond the limits imposed on logical analysis. This association of history and logic is perhaps what is most astonishing for the modern reader. We are used to separating the historical study of science from the logical analysis of its language. These methods have given rise to two philosophical traditions: analytical philosophy of science and historical epistemology.

One may distinguish four major readings of *The Aim and Structure*. I thereby qualify not individual interpretations but how the text was perceived at certain times and in certain places. My aim here is to question these readings, keeping in mind the issue of history. One should first mention the reception of his work at the turn of the 19th and 20th centuries. The context was that of the institutionalization of philosophy of science, and early readers, I believe, sought in Duhem elements for constructing the field. The second major reading was that of the logical empiricists. We know that Duhem’s conceptions, along with those of Poincaré, attracted the attention of members of the Vienna Circle. They noted the proximity of Duhem’s views to those of Mach. What interested them was Duhem’s logical analysis of theory structure. They of course downplayed the importance of history. What is intriguing in Duhem’s case is that after having inspired logical empiricists, his ideas were taken up by their critics. Quine’s allusions to Duhem are brief but significant. And the Duhem-Quine thesis was largely adopted in the postpositivist movement.

This alternate reading of Duhem eventually stimulated an interest in his work for its own sake. Undeniably, in the 1980s began a careful examination of the different aspects of his research: his physics, his philosophical theses and his historical studies. This is Duhem in context. Since then postpositivism has given way to new methods: Crombie has argued for

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styles of thinking, and Hacking has criticized the idealism of Kuhn and others. The question today is how to assess the accumulated results of Duhem studies and to go beyond. Is a new reading of Duhem possible?

1. The explicit role of history in Duhem

A historical approach to philosophy of science can be pursued in many ways, and indeed has given rise to a variety of styles of research. One direction consists in grounding philosophy of science on the history of science. Duhem's work offers in this respect a noteworthy example. In *The Aim and Structure* "logical analysis" was complemented by recourse to historical study, both entering into a detailed and complex view of the nature and goal of theoretical physics. Moreover, the numerous volumes Duhem devoted to the evolution of science from Antiquity to present bear witness to this concern. Duhem drew on the pioneering studies of Paul Tannery, who had broken away from Comte's superficial history. He brought out their philosophical implications. This endeavor in turn caught the eye of his contemporaries who were intent on establishing philosophy of science as an academic discipline. Such was the case of Rey, Milhaud and Le Roy¹. Thus emerged a historical philosophy of science strongly represented in France, Meyerson and Brunschvicg providing further examples. I hold that what will come to be called historical epistemology², as represented variously by Bachelard, Canguilhem, Foucault and Dagognet, has its origins here.

Postpositivists were later to call on this tradition in their effort to reassert the importance of history. For example, Kuhn drew on Duhem's history of cosmology in his study of the Copernican revolution and he pointed to Quine's break with logical empiricism, which was inspired by Duhem. He came to describe Duhem's role in these terms:

"Duhem's search for the sources of modern science disclosed a tradition of medieval thought which [...] could not be denied an essential role in the transformation of physical theory that occurred in the 17th century [...]. More than any other, that challenge has shaped the modern historiography of science"³.

Kuhn then took up this challenge after others, and one can follow the evolution of his thought from a moderate view of scientific change to a radical view, in reaction to Duhem's continuism. It is interesting to note that Kuhn also mentions Meyerson and Brunschvicg, precisely the type of historical philosophy of science Duhem inspired. Other postpositivists called on Duhem's arguments and historical studies, such as Feyerabend, Lakatos and Laudan.

¹ See Rey, 1904 and 1907; Milhaud, 1898; Le Roy, 1899-1900. Milhaud and Le Roy are reacting to Duhem's characteristic thesis as presented in his earlier writings.

² The expression "historical epistemology" was introduced by Dominique Lecourt in 1969 with reference to Bachelard, but he attributes the paternity to his supervisor Canguilhem. See Lecourt, 2008, p. 51.

³ Kuhn, 1977, p. 108.

However, these authors were pursuing their agenda, and it is not obvious that they provide us with a complete picture.

Let us take a closer look at the function of history in *The Aim and Structure*. Duhem's reasoning is frequently illustrated by examples taken from past science; each major claim is supported by historical arguments: representation, natural classification, analogy, etc. Furthermore, two crucial sections of the book are explicitly devoted to history, that on the representative theories and the final pages⁴. The following passage summarizes nicely Duhem's attitude:

“The legitimate, sure, and fruitful method of preparing a student to receive a physical hypothesis is the historical method. To retrace the transformations through which the empirical matter accrued while the theoretical form was first sketched; to describe the long collaboration by means of which common sense and deductive logic analyzed this matter and modeled that form until one was exactly adapted to the other; that is the best way, surely even the only way, to give to those studying physics a correct and clear view of the very complex and living organization of this science”⁵.

One should not forget the lengthy presentation Duhem gives of the genesis of Newton's principle of universal gravitation. The purpose of this passage is clearly to show that this principle did not arise from a mere generalization of Kepler's laws nor from an inductive procedure alone. The historical presentation concludes with the idea of a continuous development, which characterizes Duhem's historical view⁶. Historical continuism replaces inductivism.

Duhem was not a professional philosopher; his intention was not aimed at establishing philosophy of science within the university curriculum. He was developing a general thermodynamic or energetics. And history serves as a justification of his scientific research program⁷. His program was superseded by Relativity theory and Quantum mechanics. What remains is to some extent retrieved by the logical empiricists, that is axiomatics and the unity of physics. However, Duhem's recourse to history goes beyond the explicit role he assigns to it.

2 . Duhem's definition of theory and its historical presuppositions

It is time we turn to Duhem's well-known definition of theory: “A physical theory is not an explanation. It is a system of mathematical propositions, deduced from a small number of principles, which aim to represent as simply, as completely, and as exactly as possible a set of

⁴ See Duhem, 1906, part. 1, ch. 3; part 2, ch. 7, § 6.

⁵ Duhem, 1906, p. 408-409; trans. p. 268-269.

⁶ See Duhem, 1906, p. 384 ; trans. p. 252.

⁷ Duhem, 1913, p. 116; trans. p. 339.

experimental laws”⁸. A scientific theory is no longer conceived as the explanation of deep causes, but as an abstract representation of laws. One may perceive here an intuition of the standard view of theories, which the logical empiricists will further develop: a theory is an axiomatic system, a set of propositions deductively linked, arranged into axioms and theorems, its empirical interpretation being provided by certain operations such as measurement. Duhem goes on to explain that theory consists in a symbolic construction characterized by four operations: the definition of concepts, the choice of hypotheses, the mathematical development, and the comparison with experiment. This series of operations is what Duhem designates by structure, and the second part of his book treats of each one in turn.

Let us now apply the results of history of philosophy of science. In developing his definition Duhem was drawing on Kirchhoff. The latter wrote an important series of volumes on mathematical physics. The first in 1876 is devoted to mechanics, and begins as follows:

“The point of departure of the presentation I have chosen differs from that generally adopted. It is usual to define mechanics as the science of forces, and forces as the causes that produce motion or tend to produce them [...]. But this presentation is vitiated by the obscurity inherent in the concepts of cause and tendency”⁹.

Kirchhoff obviously has in mind here the traditional definition given by Lagrange. He then goes on to expound his own presentation: “For this reason I assign to mechanics the task of describing motions that occur in nature and of describing them indeed completely [*vollständig*] and in the simplest manner possible [*einfachste*]”¹⁰.

The description provided by mechanics then must be complete and the simplest possible. Let us pay attention to the exact formulation of this passage, which Duhem read in the light of his own concerns: simplicity alone admits of degrees; completeness is taken absolutely. If simplicity admits of degrees, it is because it refers to the possibility of scientific progress. Later in his book Kirchhoff gives a traditional example: that of the replacement of Kepler’s laws by Newton’s principle of gravitation. The progress accomplished thereby implies the use of more complex mathematics, but allows for a much more synthetic account. What we have here is a phenomenalist perspective: physics should no longer search for the causes nor be given over to the explanation of things. The concept of force can in a sense be eliminated. It only serves to simplify the mathematical expressions. The position just outlined has been qualified variously as descriptivism, positivism or nominalism.

One may make several remarks on this presentation. Does the requirement of completeness not also admit of any degrees? Duhem will sweep this restriction away. Does scientific

⁸ Duhem, 1906, p. 24; trans. p. 19. The translation follows here literally the text. In English the most current term is “accuracy”.

⁹ Kirchhoff, 1876, p. V; translation mine.

¹⁰ Kirchhoff, 1876, p. V; translation mine.

description not imply other conditions? In truth, Kirchhoff is pretty much obliged to admit it: he indeed brings up accuracy. But he does not include this concept among the explicit conditions of his definition of mechanics. This is another obvious omission of his presentation. What we have here is an attempt at a new definition of mechanics. But the enterprise is not brought to completion. Duhem will introduce significant changes. He delves deeper into the consequences of the descriptive task assign to mechanics, and now extended to science in general. But let us notice that as axiomatization no longer means explanation, the descriptive presentation of physical theories must receive from elsewhere a justification. Such are the requirements of simplicity, completeness and accuracy, which Duhem emphasizes.

We are also in a position to explain the origins of the other major elements of Duhem's conception. The idea of theory as representation, rather than explanation, goes back to Ampère¹¹. What is original in Duhem's definition is that we now have a two-tier model. What the physicist represents are not the phenomena but the experimental laws. As for the idea of symbolic construction, Duhem draws on Helmholtz. The elaboration of Duhem's conception throws further light on his intention. His definition of theory as representation goes back to 1892, a time when he was seeking to develop an empiricist conception of thermodynamics. The difficulties he encountered led him to formulate his holist thesis in 1894. His works in history of science then brought him to reject traditional interpretations and recognize the importance of medieval science. He came to develop a historical continuism. In contrast with his earlier formulation of theory in terms of nature and goal (*but*), Duhem speaks now in terms of structure and aim (*objet*)¹². The formulation takes into account his rejection of empiricist interpretations of thermodynamics and inductivist methodology. It is more abstract and will exert considerable influence.

3. The criteria of choice in historical perspective

What I wish to concentrate on are the three terms that occur in Duhem's definition of theory: simplicity, completeness and exactness – for the two last terms English language physicist would rather use comprehensiveness and accuracy. One can understand why he brings them up: he has rejected the Newtonian method of inductions as well as the procedure of crucial experiment, in summary the traditional schemes of justification. Hypotheses are now freely chosen, which does not mean that they are arbitrary; the theorist must motivate his choice.

¹¹ See Duhem, 1906, p. 72; trans. p. 51.

¹² The French term *objet* designates here that toward which the theory tends. It is less concrete in its connotations than the term *but*. One must take into account Duhem distinction between the aim of individual theories and the tendency of physical theories.

Hence the appeal to rational criteria. Let us first examine how they relate to this definition. Duhem gives the following comments with respect to the concept of exactness or accuracy:

“The various consequences [...] drawn from the hypotheses may be translated into as many judgments bearing on the physical properties of the bodies [...]. These judgments are compared with the experimental laws which the theory is intended to represent. If they agree with these laws to the degree of approximation corresponding to the measuring procedures employed, the theory has attained its goal”¹³.

Accuracy in physics then is the agreement within the accepted degree of approximation. Duhem is led to distinguish between truth in ordinary contexts and truth in physics. He goes as far as to advocate dispensing with truth altogether. In other words the scientist must take into account the exact nature of the procedure of verification or confirmation. Accuracy, as indeed other criteria, must be related to the operations constituting scientific activity.

Likewise simplicity is relativized in accordance with the definition of theory. In the second part of his book, Duhem explains what he means by primary qualities, in doing so he calls on history:

“The physicist who seeks to make his theories autonomous and independent of any philosophical system attributes an entirely relative sense to the words ‘simple quality’ or ‘primary property’; they designate for him simply a property that it has been impossible for him to resolve into other qualities”¹⁴.

Simplicity, completeness and exactness explicitly enter into the definition of theory. Reading further one encounters the requirements of consistency and fruitfulness. It is interesting to note that we already find in Duhem the standard list of criteria of theory choice that Kuhn will bring up in his second philosophy¹⁵. Of course there are some differences, but the fact that the question continues to preoccupy philosophers at the end of the 20th century is worth noting.

Conclusion

Calling on different readings of Duhem with respect to the role of history, we have been led to put into perspective several constitutive concepts of philosophy of science: structure, representation and criteria of choice. Duhem’s definition of theory prefigures the standard view given by logical empiricists; it was a stage in a long and complex process, whose roots go well back into the 19th century. Traditional views of knowledge were difficult to overturn, and several advances had to be made: a precise understanding of the different components of scientific theories and the concrete operations underlying them. Science has moved further and

¹³ Duhem, 1906, p. 25-26; trans. p. 20.

¹⁴ Duhem, 1906, p. 188-189; trans. p. 127. It is interesting that Duhem calls on Ampère in this context : his recognition that intensity of electrical current is an irreducible property.

¹⁵ See Kuhn, 1977, article “Objectivity, Value Judgment, and Theory Choice”.

further away from common knowledge; it no longer provides explanations in the usual sense. Mathematical organization and experimental research have to be understood on their own terms. Definitions and hypotheses are interlinked. The consistency of theoretical systems requires specific formal techniques of evaluation. And several epistemic values come to play.

The hypothetico-deductive presentation or axiomatics, on which Duhem lays such stress, appears to be giving way today to modeling and simulation. These techniques certainly express a prominent aspect of current scientific rationality, which is increasingly aided by the computer. Axiomatics has come to be seen as one among different procedures, and this shift has helped to direct attention to the historical context of emergence and the trajectory of style of reasoning. One may also mention another change of focus in philosophy of science from experimental testing of theories to the competition between paradigms or perhaps even negotiation among different styles of reasoning. Philosophy of science has moved away from Duhem in these respects. But if we are to make progress – and in the absence of a method analogous to experimental testing in the sense of physics – we should keep in mind, better still, we should reflect upon the elaboration of our conception over time. And Duhem is a key author in this history.

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