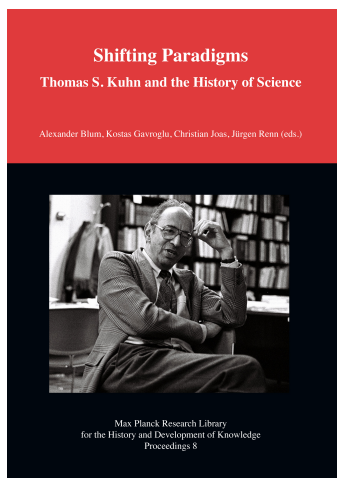


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John Stachel:

History of Science: The French Connection



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Chapter 23

History of Science: The French Connection

John Stachel

Why the French Dog Didn't Bark

Gregory (a Scotland Yard detective): "Is there any other point to which you would wish to draw my attention?"

Holmes: "To the curious incident of the dog in the night-time."

Gregory: "The dog did nothing in the night-time."

Holmes: "That was the curious incident."

Sir Arthur Conan Doyle, "Silver Blaze"

Often, the most interesting question is why the dog *didn't* bark. Here the question is: Why did Kuhn's work, which in the 1960s had such a great impact on the Anglophone history and philosophy of science communities, have so little impact on their Francophone counterparts?

In his "Translator's Preface" (Bachelard 1984, xv–xxiv), Arthur Goldhammer raised a reciprocal question:

English-speaking readers will no doubt interpret Bachelard's place in the history of philosophy in their own way. There are surely anticipations in his work of many ideas that have gained prominence in recent Anglo-American debates on the philosophy of science. But it is un-Bachelardian to look for precursors. A more salutary exercise, as he might say, would be to ask why our philosophizing didn't take a Bachelardian turn. What "epistemological obstacles" stood in the way (to borrow an expression from a work with a title similar to that of the present book: *The Formation of the Scientific Spirit*)? (Bachelard 1984, xxiii–xxiv)

So now I shall rephrase my question: What epistemological obstacles account for the Francophone dismissal of Kuhn in the 1960s? My answer is that there is a French tradition in history and philosophy of science, dating back to

Comte and still flourishing in the 1960s¹, that anticipated—and not infrequently surpassed—a number of the ideas usually attributed by Anglophones to Kuhn, as well as to Karl Popper, Imre Lakatos and/or Paul Feyerabend.

But more important, the branch of that tradition launched by Gaston Bachelard and Jean Cavaillès actually runs counter to the main ideas of the new Anglophone philosophers and historians of science. I shall illustrate this by a discussion of two 1970s critiques of Kuhn by French proponents of that tradition: one by the non-Marxist Jean-Jacques Salomon and the other by the Marxist Dominique Lecourt. Then I shall contrast this with the earlier Marxist critique of Bachelard by Jacques Solomon.²

Next I shall give a more positive account of the Bachelard-Cavaillès approach, largely in their words, and of Kuhn's missed opportunity to understand this approach. I hope this paper will encourage an Anglophone *Rettung*³ of the Bachelard-Cavaillès branch of the French tradition.

A Striking Contrast

Consider the contrast between two books, each based on a conference in the late 1960s. Figure 23.1 shows a well-known volume based on a session of the International Colloquium in the Philosophy of Science held in London, 13 July 1965, which focused on Kuhn's *Criticism and the Growth of Knowledge*. The text, “a rational reconstruction and expansion” of the discussion, does not mention Bachelard, Cavaillès or any other French scholar from the 1920s onward except Henri Bergson, whom Lakatos mentions once, and Alexandre Koyré, whom he praises in three footnotes.⁴

¹See Jay (1984, 1993) for early discussions of the Marxist strands of the French tradition, and Gouarne (2010) and Carolino (2014) for more recent discussions.

²Note that Jean-Jacques Salomon and Jacques Solomon are two quite distinct persons.

³“‘Rettungen’ nannte Lessing eine Reihe von Schriften, in denen er Autoren aus ganz verschiedenen Zeiten und Literaturgattungen öffentlich verteidigte, die das Unglück hatten, von der Mit- oder Nachwelt verfolgt oder verdammt zu sein.” Schmitt (2002): “Lessing entitled a series of writings ‘rescues,’ in which he publicly defended authors, from quite different epochs and branches of literature, who had had the misfortune to be persecuted or condemned by their contemporaries or successors,” to which I would only add: or forgotten.

⁴“The people who did most to reverse the anti-metaphysical tide in the philosophy and the historiography of science were Burt, Popper and Koyré” Lakatos and Musgrave (1970, 183). Lakatos discusses earlier Francophones Duhem, Le Roy and Poincaré at some length, and Comte in a footnote; Paul Feyerabend mentions Poincaré once, and John Watkins mentions Duhem in a footnote.

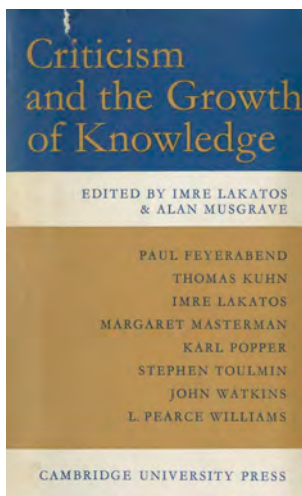


Figure 23.1: Imre Lakatos and Alan Musgrave, eds. (Cambridge University Press 1970).

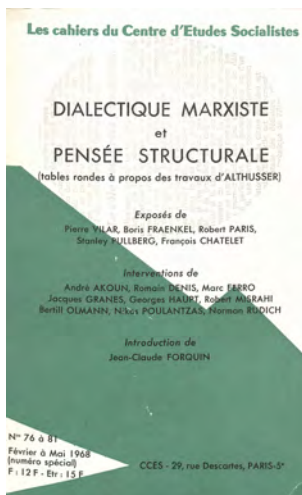


Figure 23.2: *Les cahiers du Centre d'Études Socialistes, Dialectique Marxiste et Pensée Structurale.*

Several English-language speakers (e.g., Stanley Pullberg, Bertell Ollman, Norman Rudich) participated in the four celebrated “debates,” held in Paris between 18 January and 26 April 1967, on which *Les cahiers* (1968) is based (Figure 23.2); yet it is practically unknown in the Anglophone world.⁵ Perhaps this is because, while many Italian and German scholars are cited, there is no mention of Kuhn, Popper, Lakatos or any other current Anglophone philosopher.

Mutual Neglect

Based on a conference held at the Max Planck Institute for the History of Science on “Epistemology and History from Bachelard and Canguilhem to Today’s History of Science,” Schmidgen, Schöttler and Braunstein (2012) contains an important clue to one reason for Francophone neglect of Kuhn. In the only mention of Kuhn in the book, Pierre-Olivier Méthot notes: “[...] for [Canguilhem] Kuhn misconstrues the nature of scientific rationality” (Méthot 2012, 126–127)—an accusation that recurs frequently in the Francophone literature.

Sometimes neglect was replaced by conflation. In 1975 Dominique Lecourt wrote:

Many French critics—including Marxist ones—have thought that they could detect an accord between Kuhn’s theses and the Bachelardian epistemological current. [...] To put it plainly: I think this is completely wrong. (Lecourt 1975, 9–10)

Yet the tendency to conflate Bachelard’s and Kuhn’s views continued in the Anglophone literature. Indeed, (Schuster and Watchirs 1990) is a critique of “the Kuhn/Bachelard problematic,” while (Danny 1999) is a defense of “Historical and Constructivist Philosophies of Science: Kuhn, Bachelard and Canguilhem.”

But by and large, the work of the French school in general, and of Bachelard and Cavaillès in particular, was still ignored in the Anglophone literature.⁶ As early as 1976, Robert D’Amico complained about the neglect of Bachelard:

⁵*Raison présente* (1970) is based on a similar series of articles and debates, held 22–23 and 27–28 February 1968 at the Sorbonne, and originally published in 1967–68 in *Raison présente*. Only Francophone scholars contributed, and again no Anglophone is even mentioned. Halbwachs (1972) is a notable exception. It is a report on a 1968 conference held in Geneva at the Center for Genetic Epistemology, directed by Jean Piaget, at which Kuhn presented a paper. Halbwachs discusses this paper at length, but *Structure* is not mentioned.

⁶In so far as Bachelard was remembered in the English-speaking world, it was largely for the literary aspect of his work rather than the natural-scientific. For early discussions of this dualism, see Roy (1977); Smith (1982).

His prodigious writings in the history of science, his persistent criticism of philosophy, and his critical studies of epistemology constitute the indispensable background for understanding contemporary French thought, as well as a resource for the history of the sciences which, outside of France, has been inexplicably ignored. (D'Amico 1976, 334)⁷

The first serious attempt to insert Bachelard into the Anglo-American discussion was the publication of (Bachelard 1984), the English translation of (Bachelard 1934). In his "Foreword" (Bachelard 1984, vii–xiii), Patrick Heelan wrote:

Anglo-American logical empiricism [...] has changed in many ways since Bachelard's death in the early sixties. A number of Bachelardian themes—scientific observations are theory laden, "revolutions" occur in the history of science, science is not value neutral, science is a community endeavor and reflects community interests, among others—are all presently part of the confused picture of science in the new Anglo-American philosophy of science. Although Bachelard's writings considerably antedate these changes, there is little evidence that Bachelard's views were influential to any considerable extent in bringing them about. [...] The principal agents of change within Anglo-American philosophy of science were in fact the critical writings by, to mention just a few, Stephen Toulmin, N. Russell Hanson, Paul Feyerabend, Mary Hesse, Karl Popper, as well as those by the historians of science, influenced by the work of Thomas Kuhn [...] These changes bring Bachelard's work into relevance for the mainstream of current philosophy of science in America and indicate the peculiar importance of some of his contributions—the role of the imagination, epistemology as historical, ontology as the acceptance of a value, science as an effort to produce "epistemological ruptures," the stress on instruments as constituting a "phenomeno-technology." (Bachelard 1984, xii–xiii)

Two books by Martin Jay did much to remedy this neglect (1984, chapters 9–13; 1993), but neither discusses Kuhn.⁸

⁷D'Amico (1999) is an important contribution to remedy this neglect.

⁸Jay (1984, 394, note 38) is only a reference to other sources.

An English translation (1970) of Cavaillès' posthumous major work (1960)⁹ was published in (Kockelmans and Kiesel 1970), an anthology devoted to "Phenomenology and the Natural Sciences":

The goal of this anthology is to give the English-speaking reader a first impression of the contributions made by phenomenology to the vast domain of the philosophy of the natural sciences. (Kockelmans and Kiesel 1970, xi)

Perhaps this association with phenomenology did Cavaillès more harm than good. Michel Foucault states the problem well:

It seems to me that one could find another dividing line which cuts through all these oppositions. It is the line that separates a philosophy of experience, of sense, and of subject and a philosophy of knowledge, of rationality and of concept. On the one hand, the network is that of Sartre and Merleau-Ponty; and then another is that of Cavaillès, Bachelard and Canguilhem. In other words we are dealing with two modalities according to which phenomenology was taken up in France, when quite late—around 1930—it finally begins to be, if not known, at least recognized. (Foucault 1978, x)

Kockelmans and Kiesel (1970) do not make this opposition clear. At any rate, Anglophone neglect of Cavaillès has been even greater than that of Bachelard.

By the turn of this century, things had begun to change a bit in the Anglophone world—but only a bit. The volume on Kuhn in the series *Contemporary Philosophy in Focus* (Nickles 2003) has an article on "Thomas Kuhn and French Philosophy of Science" (Gutting 2003). In his introduction, Thomas Nickles wrote:

Gutting explores parallels between Kuhn's account of science and those of the prominent French historical-philosophical tradition, including Brunschwig, Bachelard and Canguilhem. The French took a historical approach to the intellectual appraisal of science long before Kuhn and the post-Kuhnian historical philosophy of science. In several instances the French thinkers anticipated postmodern insights commonly attributed to Kuhn in the Anglophone world. Gutting suggests that the French tradition provides resources for solving

⁹"Cavaillès was a philosopher of science and mathematics, a critic of Husserl and Kant, and a (twice) decorated hero of the French resistance. The role of his work in the changes that took place in the French philosophical scene after World War II—he was executed in 1944 by a Nazi firing squad—is perhaps unfairly neglected outside of France" Tasić (2001, 84–85).

Kuhnian problems concerning objectivity, rationality, and realism.
(Nickles 2003, 12–13)

Yet there is no mention elsewhere in the volume of these three or of any other figures in this “French historical-philosophical tradition.” Quite recently, Knox Peden noted:

[A]lthough Cavaillès is beginning to procure an intrepid readership keen to understand the role played by the philosophy of mathematics in recent French thought, his student Jean-Toussaint Desanti has garnered scarcely any attention beyond the hexagon. By and large, these philosophers remain unknown quantities to an Anglophone audience. (Peden 2014, 8)

I have not made an extensive study of the German literature, but the following example leads me to suggest that it may not be exempt from similar strictures. In a book entitled *Science as a Historical Process / The Anti-Positivist Turn in the Theory of Science*, Bayertz writes:

In the wake of the reception of Kuhn’s *Structure of Scientific Revolutions* a historical understanding of science began to prevail, the goal of which is the philosophical analysis of scientific praxis and its transformations in the course of history. Besides Thomas Kuhn, Stephen Toulmin, Norwood Russell Hanson, Imre Lakatos and Paul K. Feyerabend are among the representatives of this anti-positivistic current. (Bayertz 1980, 7)¹⁰

There is no mention of Bachelard, Canguilhem, Cavaillès, Foucault or any other French source of this “anti-positivistic current.”¹¹

Two French Critics of Kuhn

In the early 1970s, two French exponents gave accounts of the Bachelard-Cavaillès approach to epistemology that emphasized its differences with the Kuhn approach. One, Jean-Jacques Salomon, was head of the Science Policy Division of the OECD and a non-Marxist. The other, Dominique Lecourt, was a self-described “Marxist-Leninist in the domain of epistemology” (Lecourt 1975, 8). Fortunately, both their accounts are available in English (Salomon 1973; Lecourt 1975). Both were students of Canguilhem, who in turn was a student of

¹⁰Unattributed translations are by the author.

¹¹Here too, the tide has begun to turn more recently. See, e.g., Rheinberger (2005); Schöttler (2012).

Cavaillès; so, while referring often to Bachelard, they acknowledge their debt to Canguilhem rather than directly to Cavaillès:

Raymond Aron and Georges Canguilhem encouraged a work which was threatened by many professional constraints, and were kind enough to allow him to go forward under the auspices of the Sorbonne. (Salomon 1973, xxii)

Gaston Bachelard's Historical Epistemology, written under the guidance of Georges Canguilhem and published thanks to him, dates from the autumn of 1968. (Lecourt 1975, 8)

Althusser, on the other hand, was directly inspired by Cavaillès, as Warren Montag emphasizes:

[T]his early essay by Althusser [...] sketches out a critique of both sides of the debates that raged in French philosophy in the 1950s: consciousness or structure, or in Althusser's terms, subjectivism or formalism, both of which positions could be, and often were, defended with citations from Husserl. His critique, although couched in Marxist terms, was in fact drawn from two thinkers whose influence on Althusser was enormous: Jean Cavaillès and Georges Canguilhem. It is Cavaillès in particular who figures most centrally in Althusser's examination of the alternatives around which French philosophy, especially insofar as it addressed the problem of scientific knowledge, appeared to be structured. His most influential work was his last, *Sur la logique et l'histoire de la science*, written in prison in occupied France in 1943. (Montag 2013, 40)

Now I shall turn to the content of the two critiques.

1) Jean-Jacques Salomon

Salomon establishes his debt to Bachelard:

All contemporary research consists of reciprocal feedback between concept and application, between theory and practice, or, in Bachelard's words between 'the mind which works' and 'the matter which is worked.' In this relation *theoria* is the first instance of *techné*, in time if not in the hierarchical sense, and without its epistemological priority bearing a constant relation to the technical

achievements which justify it; the road to the conquests of science lies through the conquests of technology. (Salomon 1973, 77)

But the tree of science also hides the forest: scientific research does not consist solely in science in the sense of knowledge which is the sole source of applications. *From the most abstract reflection through to development, scientific research constitutes a process whose different elements are so many links in a continuous and retroactive system.*

‘The two societies, the theoretical society and the technical society [says Gaston Bachelard, with great truth], are in contact with each other. They cooperate. They *understand* each other.’ (Salomon 1973, 81)

What Bachelard said about a rationalized theory of electricity in fact applies to the whole structure of contemporary scientific research:

‘The rational and the real must be apprehended together in a veritable coupling in the electromagnetic sense of the word, constantly stressing the reciprocal reactions of rational thought and technical thought.’

This idea of coupling represents movement from the most theoretical to the most applied research and movement back again not as a fortuitous transition from intellectual adventure to technology, but as *the deliberate organization of reciprocal exchange*. [...] Scientific research results in discoveries which are also inventions, in inventions which are also discoveries: *It is the deliberate and organized application of human labour to the production of new knowledge, processes and products.* (Salomon 1973, 83–84)

Then he distinguishes this approach from that of Kuhn:

[Jantsch] challenges the whole idea of a ‘pure’ science with characteristics of such a kind that its evolution cannot in any way be foretold. This is the theory of what he calls the ‘encapsulation’ of science—its withdrawal into an ivory tower, immune from the pressures of the profane world—and of which he finds, not without reason, one of the best examples in the book by Thomas Kuhn, *The Structure of Scientific Revolutions*. According to Kuhn, scientific progress is made up of two sorts of movement, that of ‘normal science’ which develops within the limits of established

‘paradigms’, and that of science in a period of crisis, when the revolution set off by the ‘anomalies’ of the concepts in use takes the form of strife between the old and the new ‘paradigms’, until the victory of the new concepts, recognized and adopted, gives rise to a new ‘normal science’.

In many respects Kuhn’s anomalies recall the ‘epistemological obstacles’ of Bachelard in *La formation de l’esprit scientifique* (1938, 91). But, just as the idea of ‘paradigm’ is vague, so that of the ‘epistemological obstacle’ is precise and rich to the point of being the principle which explains the ‘anomalies’ themselves (Salomon 1973, 112).

This assuredly ‘purist’ conception, which rejects all influence over the course of science other than that of its own problems, contrasts at the opposite extreme with the conception of the ‘integration’ of science in the social system. The empirical course of history takes precedence here over the theoretical consideration of knowledge, as though knowledge had no significance except in so far as it is conditioned by history. *If these conceptions are diametrically opposed, it is not so much because they both alike find illustrations founded on the facts, but rather because they each refer back to irreconcilable ideologies.* We have a dialogue of the deaf, because each camp refers to an objective which could be defined independently of the values it attaches to the objective.

Both positions [said Georges Canguilhem] come down to treating the subject of the history of science as the subject of a science.

Hindsight or foresight, the misapprehension is the same; If one finds, here and there, formulated in terms as absolute as those of the ‘idealistic’ interpretation, the conception of the total integration of science in society, it is because the subject of reflection is in both cases presumed to be determinable *as the subject of a science.* (Salomon 1973, 113)

2) Dominique Lecourt

Now I turn to Dominique Lecourt. His “Introduction to the English Edition” (1975, 7–19) took up the challenge of describing what he saw as the sharp distinction between the approaches of Bachelard and Kuhn:¹²

The New Scientific Mind, Gaston Bachelard’s first great epistemological work, was published in 1934, the same year in which Karl Popper’s famous book *The Logic of Scientific Discovery* appeared in Vienna. During the subsequent thirty years the works of the one and the other have been developed, enriched, corrected and broadcast without it ever being possible to register either the beginnings of a confrontation or a sign of any emulation between them. [...] However, two recent events [have led to] a serious misunderstanding. These two events are [...] the translation of Althusser’s works into English and [...] the appearance a short time ago of Thomas Kuhn’s *The Structure of Scientific Revolutions* in French. A number of British commentators have seen ‘convergence’ if not identity pure and simple of the epistemological positions defended by Althusser and by Kuhn. Many French critics—including Marxist ones—have thought that they could detect an accord between Kuhn’s theses and the Bachelardian epistemological current. [...] To put it plainly: I think this is completely wrong. (Lecourt 1975, 9–10)

But he starts by describing the role of Althusser in current French Marxism:

A theoretical encounter [...] which has brought together, in France, dialectical materialism—Marxist philosophy—and a certain epistemological tradition inaugurated by Gaston Bachelard. The site of this unexpected encounter [is] the work of Louis Althusser [...]. Let me say straight away: for more than ten years now this encounter has whipped up an incredible series of political storms in the Marxist camp. On this side of the Channel the whirlwinds of these storms have not yet stopped forming and reforming. [...]

[U]ntil 1968 the wind of criticism was set from the right, from ‘Ga-raudyism’, from that so-called ‘Marxist humanism’ [...] Althusser was then accused of ‘scientism’ and ‘dogmatism’. These attacks

¹²In the body of Lecourt (1975), there is no mention of Popper, Lakatos or Kuhn. The only philosophers writing in English that he mentions, such as Bernal, Price and Reichenbach (p. 121), are characterized as positivists.

took as their main theoretical target the notion of ‘epistemological break’ which he had borrowed from the works of Gaston Bachelard.

Bachelard had coined it to remind the historians of science, too inclined to continuism, that a science is only installed by breaking with, by *cutting* itself off from its own past; that the object of a science is therefore not an immediate given and does not pre-exist the process of its production. (Lecourt 1975, 7)

[T]he dominant tendency of the Bachelardian tradition is materialist whereas the tendency ‘Popperism’ and its variants is, despite certain appearances, frankly idealist. [...] I shall examine two texts in which the proximity of the two traditions might seem flagrant: on the one hand, Bachelard’s *The Rationalist Activity of Contemporary Physics*; on the other, *The Structure of Scientific Revolutions*. These two books do indeed seem to be in accord in essential matters. (Lecourt 1975, 10)

Lecourt lists three points of “apparent proximity”:

[B]oth present a *discontinuist* conception of the history of the sciences [...] both present, unevenly developed, a reflection on the scientific division of labour, and its material instances [...]. Finally [...] both speak of the ‘normality’ of science. (Lecourt 1975, 10)

Then he critically examines them. He starts by explaining Bachelard’s approach:

[W]ith the expression [epistemological value] Bachelard is aiming at a tendency within the philosophy of sciences itself: the positivist tendency. Against the dissertations about the ‘value of science’ which have been traditional since Poincaré, against the skeptical and relativist professions of faith to which they have given rise, Bachelard invites the epistemologists to take cognizance of the constant emergence of new epistemological values in contemporary scientific practice. [...] The notion of epistemological value thus also has the function of combating what he calls [...] a ‘vague relativism’ and an ‘outmoded scepticism.’ (Lecourt 1975, 11–12)

The history of the sciences is the history of the defeats of irrationalism. But the fight is without end [...]. (Bachelard 1951, 27)

Bachelard expresses this thesis a hundred times in his last works: in it he sees what he rightly calls the very *dialectic* of scientific thought.

Hence one can argue without paradox that Bachelard is defending a position which is both *materialist* and *dialectical* in philosophy. From this position in philosophy he is able to revolutionize the status of epistemology: to institute what I have called a historical epistemology and to demarcate himself radically from every form of positivism. (Lecourt 1975, 13)

Then he turns to Kuhn:

Kuhn [...] picks up one answer after another to an insoluble question. The very question that Bachelardian epistemology refuses to ask; the question on the repudiation of which it has established its own terrain: the idealist question of the objectivity of scientific knowledges (how is it guaranteed? How is it to be founded?) No doubt Kuhn poses this question in terms that seem ‘concrete’, current and scientific: there is no question in his work either of a *cogito* or of a transcendental subject, it is a question of ‘scientific groups’, of laboratories, and it is in this that the book ‘speaks’ to the scientists of today—better no doubt than Bachelard’s works—but it is essential not to be taken in by words: the theoretical core of this work is an old philosophical notion, an idealist question accompanied by the cortege of answers it imposes, in the circle of which Kuhn—and not he alone—has allowed himself to be trapped.

That is why, despite the ‘discontinuum’ and a few other appearances it seems to me, decidedly, that the two tendencies of contemporary epistemology cannot meet. I repeat: this is because of a reason of position in *philosophy*. The one is, timidly and confusedly but indisputably, ranged in the materialist camp, the other is inscribed in the orbit of idealist philosophies. (Lecourt 1975, 18–19)

Jacques Solomon

As Lecourt makes clear, he was following Althusser in his positive evaluation of Bachelard. But he was not the first French Communist to discuss Bachelard. During the 1930s Jacques Solomon was a prominent physicist as well as a Party militant.¹³ He was a close friend of Leon Rosenfeld, visited Bohr several times, and was an advocate of the Bohr-Rosenfeld approach to quantum mechanics and

¹³See Bustamante (1997).

quantum field theory. Ironically, after WWII this would have brought him into direct conflict with the Soviet “Diamatchiki” and their French adherents.

Written in 1942 and posthumously published, (Solomon 1945) is a critique, of (Bachelard 1940) for its idealist conception of science—just the inverse of (Lecourt 1975), which as we have seen defends Bachelard as a materialist. In Bachelard’s extensive discussion of quantum theory in the book, there is no reference to Bohr; and this absence may well have influenced Solomon’s negative judgment of the book.

Bachelard sees things backwards. He constructs a labyrinth of concepts in order to try and extract reality from the physicist’s head; however the physicist attempts to extract his ideas from reality.

It is thus not quite exact to declare like Bachelard that “the veritable solidarity of the real is essentially mathematical”: actually, it is the real which dictates and verifies the mathematical.

Every step forward, every modification of our concepts of the structure of matter thus shows that, contrary to the opinion of Le Roy, for whom “the facts are the *facts*” (an opinion shared by Bachelard, for whom science is a *phenomeno-technology*), one cannot understand the development of science unless one conceives it as the ever more exact reflection of external reality in our minds. (Solomon 1945, 50, 51)¹⁴

Solomon is here espousing Lenin’s reflection theory of knowledge (Lenin 1909, 1947), which only recently had been so devastatingly criticized from a Marxist point of view by the Dutch astronomer and long-time militant Anton Pannekoek (1938, 1975). Solomon concludes by magnanimously recognizing Bachelard’s dialectic, and blaming his idealist approach for all the book’s errors.

Following Bachelard on the terrain of contemporary physics, we were thus forced to recognize that the very evolution of that science

¹⁴“M. Bachelard voit les choses à l’envers. Il construit un labyrinthe de concepts pour essayer de tirer la réalité de la tête du physicien, cependant que le physicien s’efforce de tirer sa pensée de la réalité. [...] [I]l n’est donc pas exact de déclarer avec M. Bachelard que “la véritable solidarité du réel est d’essence mathématique”: c’est le réel, en vrai, qui dicte et vérifie le mathématique. [...] Chaque pas en avant, chaque modification de nos conceptions de la structure de la matière montrent ainsi que, contrairement à l’opinion de M. Le Roy pour lequel “les faits sont les *faits*” (opinion que rejoint M. Bachelard pour lequel la Science *est une phénoménotechnie*), l’on ne peut comprendre le développement de la science si l’on conçoit celle-ci comme le reflet toujours plus exact de la réalité extérieure dans notre conscience.”

refutes his views, and we have seen that this originates in the idealist conception that forms the basis of Bachelard's philosophy; and which has been refuted and continues to be refuted ceaselessly by the progress of physics, as of the other sciences. [...] One can only congratulate him for having been able to recognize the manifestations of a dialectic in modern physics, of which we have given several examples. But, in our opinion, precisely because his philosophy is idealist he does not reach a correct recognition of its fundamental features. (Solomon 1945, 54–55)¹⁵

Bachelard and the “Epistemological History of the Sciences”

Now I shall try to present more positive, less polemical accounts of what Bachelard and Cavaillès actually accomplished.¹⁶ Shortly after Bachelard's death in 1962, Georges Canguilhem penned the following tribute:

In so profoundly renewing the meaning of the history of the sciences by rescuing it from its previously subordinate position, in promoting it to the position of a first-rank philosophical discipline, Gaston Bachelard did more than clear a path: he set a goal. (Canguilhem 1963)¹⁷

Dominique Lecourt and Michel Pêcheux and Étienne Balibar elaborate:

For almost a quarter of a century, Bachelardian epistemology has consisted of close attention to the contemporary progress of the physical and chemical sciences, an incessant polemical vigilance with respect to philosophical theories of knowledge; and, as the fruit of these combined interests, a progressive rectification, through a constant “self-polemic,” of its own categories. [...] [T]his “historical epistemology” opened the way for a new discipline, in which

¹⁵“En suivant M. Bachelard sur le terrain de la physique contemporaine, nous sommes donc contraints de reconnaître que l'évolution même de cette science infirme ces vues et nous avons reconnu que l'origine en est dans la conception *idéaliste* qui est au fond de la philosophie bachelardienne et qu'a réfutée et qui réfute sans cesse le progrès de la physique, comme des autres sciences. [...] On ne peut que le féliciter d'avoir su reconnaître dans la physique modern les manifestations d'une dialectique dont nous avons plus haut indiqué quelques exemples. Mais justement parce que sa philosophie est idéaliste, notre auteur n'arrive pas, à notre avis, à en reconnaître correctement les traits fondamentaux.”

¹⁶See Bachelard (1971) and Ginestier (1968) for surveys based on extensive excerpts.

¹⁷“En renouvelant ainsi profondément le sens de l'histoire des sciences en l'arrachant à sa situation jusqu'alors subalterne, en la promouvant au rang d'une discipline philosophique de premier rang, Gaston Bachelard a fait plus de que frayer une voie, il a fixé une tâche.”

others since then have taken part: “the historical epistemology of the sciences.” (Lecourt 1972)¹⁸

In the historical process of formation of scientific physics, the point of “no-return” (to use F. Regnault’s expression), with which that science begins, is called the *epistemological break*. [...] The term “point of no-return” constitutes a taking of sides in the polemic in epistemology and history of science between a “continuist” position (Brunschvicq and the permanent play of the human mind in science, Duhem and the question of precursors [...]) and a “discontinuist” position that may be conveniently designated by the names of Bachelard and Koyré. (Pêcheux and Balibar 1969, 8–9)¹⁹

Cavaillès, Canguilhem, and Foucault

Bachelard always felt very close to Cavaillès and in (Ferrières 1950) paid tribute to his fallen friend and ally:

And we had our projects: jointly defending rational thought, returning philosophy to the demands of testing. I admired the rigor of a philosophy that was intended to be demonstrative. Even in abstract thought, Jean Cavaillès had a heroic willpower. (Ferrières 2003, 137)²⁰

The work of Jean Cavaillès cannot be summarized. One cannot even single out its general characteristics because all of its chapters and

¹⁸ “[L]’épistémologie bachelardienne [...] se constitue d’une attention tendue, pendant près d’un quart de siècle, aux progrès contemporains des sciences physique et chimique, d’une vigilance polémique sans défaillance à l’égard des théories philosophiques de la connaissance, et, fruit de ces intérêts combinés, d’une rectification progressive, dans une “autopolémique” constant, de ses propres catégories. [...] [C]ette “épistémologie historique” ouvrirait le champ d’une nouvelle discipline, où d’autres, depuis, se sont engagés, “l’histoire épistémologique des sciences.”

¹⁹ “Dans le processus historique de formation de la physique scientifique, on appellera coupure épistémologique le point de “non-retour” (selon l’expression de F. Regnault) à partir duquel cette science commence. [...] Le terme de “point de non-retour” constitue une prise de position dans la polémique qui oppose en épistémologie et en histoire des sciences une position “continuiste” (Brunschvicq et le spectacle permanent de l’esprit humain présent dans la science; Duhem et la question des précurseurs [...]) à une position “discontinuiste” qu’on peut désigner commodément par les noms de Bachelard et de Koyré.”

²⁰ “Et nous fîmes des projets: défendre ensemble la pensée rationnelle, rappeler la philosophie aux exigences de la preuve. J’admirais la rigueur d’une philosophie qui se voulait démonstrative. Déjà dans la pensée abstraite, Jean Cavaillès avait une volonté de héros.”

even its pages were written with a will to give only the *essence* of his thoughts. Nothing is superfluous, nothing even explanatory in such an exposition. [...] By working in such a compact style, Cavaillès was acting in obedience to an ideal. [...] For Cavaillès, *every pure thought* had to be a *sure thought*, discursively attached to his criteria. [...] For him, a rationalism that pursued a slow historical growth did not suffice. He believed that contemporary mathematical science installed us straight off in abstract, autonomous thought. [...] In Cavaillès' thought, the same condemnation liquidated psychologism and historicism. He wrote, in a formulation of marvelous density, "Nothing is so little historical [...] as the history of mathematics." (Ferrières 2003, 238–239)²¹

Even posthumously, Cavaillès played a major role. In 1967, François Chatelet spoke of:

This epistemological movement of which, in the natural sciences, works such as those of Cavaillès, of Koyré, of Bachelard and of Canguilhem have given us the analysis. (*Raison présente* 1970, 277)²²

The fullest account of Cavaillès' role in mathematics is (Sinaceur 1994). Tasić (2001) gives the best discussion in English of Cavaillès' significance today:

[I]f we think of Hilbert's plan in terms of its self-proclaimed proximity to Kant, then we can think of Cavaillès' philosophy of science as, so to speak, doing a little Hegel on Hilbert's "Kant." [...] But first let me introduce Cavaillès and indicate why I think he can be viewed as bridging the great divide between Hilbert's formalism and certain parts of postmodern theory. [...] I will concentrate on his influence on Foucault, but it extends much further than that. Skipping over unnecessary details, let me simply say that Cavaillès'

²¹"L'oeuvre de Jean Cavaillès n'est pas une oeuvre qu'on puisse résumer. On ne peut même pas en dégager les caractères généraux, car tous les chapitres, et les pages elles-mêmes, ont été écrits avec une volonté de ne donner que l'essence des pensées. Rien de superflu, rien même d'explicatif, dans un tel exposé. [...] En travaillant d'une manière aussi serrée, Cavaillès obéissait à un idéal. [...] Pour Cavaillès, *toute pensée pure* devait être *pensée sure*, pensée discursivement attachée à ses critères. [...] Une rationalisme suivant une lente croissance historique ne lui suffisait pas. Il estimait que la science mathématique des temps modernes nous installait d'emblée dans une pensée abstraite, autonome. [...] Une même condamnation, dans la pensée de Cavaillès, liquidait le psychologisme et l'historicité. Il a écrit, dans une formule d'une merveilleuse densité: "Il n'y a rien de si peu historique [...] que l'histoire mathématique."

²²"[C]e mouvement épistémologique dont [...] dans les sciences de la nature, des travaux comme ceux de Cavaillès, de Koyré, de Bachelard et de Canguilhem nous ont donné l'analyse."

work helped remove the “spell” that the intuitionist Bergson and the existentialist Sartre cast on French philosophy.

Cavaillès [...] spoke of “science of science,” blurred meta-mathematics into mathematics, and maintained that the truth is *in* the demonstration, *in* the method itself. [...] He went after the “philosophy of the subject” in general, especially Husserl’s and Kant’s ahistorical intuitions. Cavaillès’s science of science appears to be blessed with a “Hegelian” slant, which is clear from his rejection of the pure/applied dualism, his critiques of the philosophy of individual consciousness, and his concern for change and movement that constitute the structure through which science manifests itself *to itself*. This is not unlike Hegel’s spirit, which through a dialectical movement comes to know itself *as* that very movement.²³

Science cannot be reduced to the intentions of individual scientists, but is an entity in itself. Applying this to the particular case of mathematics, we get the following picture. A theorem is not true because *someone* got an idea and then applied the universal, immutable laws of logic or mathematics, thereby proving the theorem. Rather, the “truth” of the theorem is in its very demonstration, which represents a necessary movement within the structure of science itself. “The true meaning of a theory is not in what is understood by the scientist, he wrote in *On Logic and the Theory of Science*, “but in a conceptual becoming that cannot be halted.”

Following this idea, we come across Cavaillès’ line that scientific progress is not a history of accumulation of truths but a perpetual revision through deepening and erasure. On this view, the task of historians of science is to study the *constitution* of truth as a historical concept within an era, rather than to study what was

²³Brendan Larvor (1998) has drawn attention to the parallels between Cavaillès’s and Lakatos’ views of mathematics. In 1938 Cavaillès wrote to a committed Marxist friend: “*Quoique philosophiquement je ne sois pas orienté par le materialism dialectique [...] je t’avais déjà dit que je me trouvais conduit à des resultants qui ne sont peut-être pas tellement exclus par votre attitude*” (Gouarné 2010, 369), which notes that the letter is cited by H. Mougin, “Jean Cavaillès,” *La Pensée*, 4, juillet-septembre 1945, p. 70–83, p. 79. “Although philosophically I am not oriented by dialectical materialism [...] I have already told you that I find myself led to results that are perhaps not excluded by your point of view.”

believed to be true in that era.

There is a strong historical link between Cavaillès and Foucault. Foucault himself acknowledges his debt to the French historian of science Georges Canguilhem, his mentor. Canguilhem, on the other hand, admired Cavaillès's work and personal courage—even wrote a book about him, *Vie et mort de Jean Cavaillès*—and was one of the people whose influence paved the way for postmodern theory in the somewhat rigid world of the Parisian academia. (Tasić 2001, 84–86)

The Bachelard-Cavaillès Approach

Finally, I shall let Bachelard explain, with some excerpts from (Bachelard 1950) what I call the Bachelard-Cavaillès approach to the natural sciences:

As Cavaillès says, “Every observation must be changed into a demonstration.” [...] This epistemological substitution is ever more necessary as, with the infinite, science approaches a domain where verification is not possible. “Through a revolutionary reversal, it is number that is driven out of the realm of perfect rationality, and the infinite which comes into it.” (Cavaillès 1970, 370). “Perhaps for the first time,” with Bolzano “science is no longer considered as a simple intermediary between the human mind and being in itself, depending as much on one as on the other and not having its own reality. Now science is regarded as an object *sui generis*, original in its essence, autonomous in its movement.”

Can one conceive of a better formula for defining the new “meta-science” situating scientific knowledge in its specific being, in its independent being! Henceforth, science is a human creation, about which the human mind should be learning, be constructing. No longer could it be accepted naively, no longer could it be developed empirically, even were it an empiricism of intellectual discoveries. Its unity is always in movement: “Since it is a question here not of a scientific ideal, but of realized science, incompleteness and the requirement of progress are part of its definition.”

In passing Cavaillès notes the philosophical weakness of an epistemology that believes the sciences may be characterized as

hypothetico-deductive systems: “How can a principle or a union of principles, which in their content and in their totality are not themselves intelligible, be the starting point for an intelligible development? The heterogeneous alliance of a verified pure concrete and a mode of rational sequence is a simple image without thought.”

So here is the problem of a theory of science for a contemporary philosophy of science: to understand science in its creative process, “to find this structure again, not by description but apodictically, insofar as it elaborates itself and demonstrates itself. In other words, the theory of science is an a priori, not prior to science but the soul of science.” (Ferrières 2000, 371–2, 374)²⁴

“Kuhn’s Missed Opportunity”

A number of critics of Kuhn have emphasized the priority of the French tradition in philosophy and history of science. Gary Gutting discussed this issue in his articles (1990;²⁵ 2003) and book (2001). In “Continental Philosophy and the History of Science,” he distinguishes this tradition from the other major trends:

²⁴“Il faut changer, comme dit Cavaillès, “toute constatation en démonstration.” [...] Cette substitution épistémologique est d’autant plus nécessaire que la science aborde, avec l’infini, un domaine où l’on ne peut constater. “Par un renversement révolutionnaire, c’est le nombre qui est chassé de la rationalité parfaite, l’infini qui y entre.” Pour la première fois peut-être avec Bolzano, “la science n’est plus considérée comme simple intermédiaire entre l’esprit humain et l’être en soi, dépendant autant de l’un que de l’autre et n’ayant pas de réalité propre, mais comme un objet sui generis, original dans son essence, autonome dans son mouvement.”

Peut-on concevoir meilleure formule pour définir la nouvelle “métascience” posant le savoir scientifique dans son être spécifique, dans son devenir indépendant! La science est, désormais, une création humaine sur laquelle l’esprit doit s’instruire, se construire. On ne peut plus le recevoir naïvement, on ne peut plus la développer empiriquement, fût-ce comme un empirisme des trouvailles spirituelles. Son unité est toujours en mouvement: “Comme il ne s’agit pas ici d’un idéal scientifique, mais de la science réalisée, l’incomplétude et l’exigence de progrès font partie de la définition.”

Cavaillès note au passage la faiblesse philosophique d’une épistémologie qui croit pouvoir caractériser les sciences comme des systèmes hypothético-déductifs: “Comment un principe ou une réunion de principes qui, dans leur contenu et dans leur assemblage, ne sont pas eux-mêmes intelligibles, peuvent-ils être point de départ pour un déroulement intelligible? L’alliance hétérogène d’un concret pur constaté et d’un enchaînement rationnel est simple image sans pensée.”

Voici donc le problème d’une théorie de la science pour une philosophie de la science des temps modernes: il faut appréhender la science dans son procès créateur, en retrouver la “structure non par description, mais apodictiquement en tant qu’elle se déroule et se démontre elle-même. Autrement dit, la théorie de la science est un a priori, non antérieur à la science, mais âme de la science.”

²⁵Most of the article is devoted to section 3: “The French Network: Bachelard, Canguilhem and Foucault” Gutting (1990, 133–146).

The phenomenological and Marxist approaches to science discussed so far have operated on a rather high level of philosophical generalization and have paid little attention to specific episodes in the history of science. There is, however, a major twentieth-century French approach to the philosophy of science that is deeply and firmly rooted in the history of science. This approach is closely tied to a long French tradition in the history and philosophy of science that began with Comte and was continued in the work of Duhem, Poincaré, Meyerson and Koyré. The central figures of this approach are Gaston Bachelard, who developed his views on science in a series of books published from the 1920s through the 1950s, and Georges Canguilhem, Bachelard's successor as director of the Institut d'Histoire des Sciences et des Techniques at the University of Paris. [...] Although not so well known outside of France, Bachelard and Canguilhem have provided a major alternative to both the phenomenological and the Marxist approaches to science.

Because of his demand that the philosopher of science work from the historical development of the sciences, the centre of Bachelard's philosophy of science is his model of scientific change. This model is built around three key epistemological categories: epistemological breaks, epistemological obstacles and epistemological acts.

Bachelard employs the concept of epistemological break (*rupture*) in two contexts. First, he uses it to characterize the way in which scientific knowledge splits off from and even contradicts common-sense experiences and beliefs. [...] The second sort of epistemological break is that which occurs between two scientific conceptualizations. For Bachelard, the most striking and important of such breaks came with relativity and quantum theory, which he saw as initiating a 'new scientific spirit'. This 'new spirit' involved not only radically new concepts of nature but also new concepts of scientific method (e.g. new criteria of scientific adequacy. Bachelard's detailed treatments of this topic preceded by two or three decades similar discussions by Anglo-American historians of science such as Kuhn and Feyerabend. (Gutting 1990, 133–4)

Kuhn himself, unfortunately, had only a glancing contact with this tradition and no serious understanding of it. The main contact came

through Koyré.

Kuhn was, like so many historians of science of his generation, strongly influenced by Alexandre Koyré, but the influence was primarily historiographical not philosophical. (Gutting 2003, 45, 63)

Kuhn himself comments on Koyré:

Trained as a philosopher and historian of philosophy, Koyré's transition to the history of science was marked by the publication in 1939 of his three brilliant *Études galiléennes*. Within a decade [...] they and his subsequent work provided the models which historians of science increasingly aimed to emulate. More than any other single scholar, Koyré was responsible for the first stage of the historiographical revolution [...] Koyré showed how sympathetic and extended *explications de textes* could transform our image of the Scientific Revolution of the seventeenth century and of the men who made it. (Kuhn 1970, 67–68)

[S]hortly before Alexandre Koyré died [...] I had a last letter from him. [...] He said, "I've been reading your book," and I don't know what adjective he used, but it was a thoroughly agreeable one. He said, and again I had not seen this coming—when I thought about it, I thought he was right—he said, "You have brought the internal and external histories of science, which in the past have been very far apart, together." Now, I hadn't thought of that at all as what I was doing. I saw what he meant, and coming from him it was particularly agreeable because he had been so anti-external history; his gifts were as an analyst of ideas. And that made an impression, or at least it pleased me tremendously. (Kuhn 2000, 286)

Koyré advised Kuhn to visit Bachelard. Gutting summarizes what happened:

Koyré [...] urged him to meet Bachelard and provided a letter of introduction. The upshot, as Kuhn tells the story, was more a comedy of errors than a meeting of great minds. To begin with, Kuhn had the idea—no doubt vaguely based on information about Bachelard's interest in the literary imagination—that he was an expert on English and American literature and so would surely speak English. "I assumed he would greet me and be willing to

talk in English.” But, although Kuhn opened with “My French is bad, may we talk English?,” the “large burly man in his undershirt [who] came to the door [...] made me talk French.” We can well understand that, as Kuhn puts it, “this all didn’t last very long.”

Kuhn says he later read a bit more of Bachelard and thought he was on to something but that his thought was too constrained by preset categories: “he had categories, and methodological categories, and moved the thing up an escalator too systematically for me.” Nonetheless, Kuhn concluded, “there were things to be discovered there that I did not discover, or did not discover in that way.” Here, at least, Kuhn’s judgment of Bachelard was correct. There are substantial similarities in the approach and problems of Kuhn’s philosophy of science and those of Bachelard’s tradition, and these similarities can sustain a mutually fruitful dialogue, even though the exigencies of history prevented it from actually occurring between Kuhn and Bachelard. (Gutting 2003, 45–46)

As Castelhão (2004) puts it, this was “Kuhn’s missed opportunity.” As noted in the Preface to (Tiles 1984), this places Bachelard and Kuhn in an even broader context:

The reception of [Bachelard’s] thought could not have been predicted. On the one hand, although Bachelard was no Marxist, various of his views were appropriated by a whole generation of Marxists. On the other hand, the impact he made on analytical philosophy in the central area of his interest, philosophy of science was, quite unjustly, negligible. His historicism, which preceded that of Kuhn or Foucault, has never been properly discussed. [...]. Mary Tiles shows in this book how Bachelard’s views are related to the concerns which analytic philosophers have about the status of science and rationality and their debates concerning realism, operationalism and relativism. [...] Dr. Tiles makes this clear by relating many of Bachelard’s arguments to those of thinkers like Putnam, Lakatos, Feyrabend or Van Fraassen. (Martin 1984, xi–xii)

Conclusion

Mary Tiles has published a remarkable defense of the historical epistemology/epistemological history of Gaston Bachelard and Georges Canguilhem

against a direct assault on it by Bruno Latour (Tiles 2011). I shall not attempt to summarize her argument, but simply urge everyone to read it and ponder its message:

[H]istorical epistemology, as defined by Bachelard and Canguilhem and extended by Bourdieu [has much to contribute to] problems that require engagement with the politics of nature, with the politics of the sciences of nature and with the epistemological challenges associated with the need to deploy multiple disciplines in the service of complex, practical, policy relevant problem solving. (Tiles 2011)

In several earlier papers, I have tried to help develop a new view of the social role of scientific knowledge (Stachel 1974; 1994; 1995; 2003; 2012). I can only hope that this article may contribute modestly to an *aggiornamento* of the Bachelard-Cavaillès tradition.

References

- Althusser, L. (1969). *For Marx*. London: Allen Lane The Penguin Press. Translation by Ben Brewster of *Pour Marx*. Paris: Maspero 1966.
- Bachelard, G. (1934). *Le nouvel esprit scientifique*. Paris: Presses Universitaires de France.
- (1938). *La formation de l'esprit scientifique*. Paris: Vrin.
- (1940). *La Philosophie du Non, essai d'une philosophie du nouvel esprit scientifique*. Paris: Alcan.
- (1950). L'œuvre de Jean Cavaillès. In: *Jean Cavaillès, philosophe et combattant 1903-1944* by G. Ferrières. Paris: Presses universitaires de France, 235–248.
- (1951). *L'activité rationaliste de la physique contemporaine*. Paris: Presses Universitaires de France.
- (1971). *Épistémologie. Textes choisis par Dominique Lecourt*. Paris: Presses Universitaires de France.
- (1984). *The New Scientific Spirit*. Beacon Press.
- Bayertz, K. (1980). *Wissenschaft als historischer Prozess: Die antipositivistische Wende in der Wissenschaftstheorie*. Paderborn: W. Fink.
- Bustamante, M. C. (1997). Jacques Solomon (1908–1942): Profil d'un physicien théoricien dans la France des années 1930. *Revue d'histoire des sciences* 50:49–88.
- Canguilhem, G. (1963). L'histoire des sciences dans l'œuvre épistémologique de Gaston Bachelard. *Annales de l'université de Paris*:24–39.
- (1978). *On the Normal and the Pathological*. Dordrecht/Boston/London: Reidel.
- Carolino, F. (2014). *Scienza e ideologia «à la lumière du marxisme» Il contributo del Cerchio de la Russia nuova nel processo di elaborazione e attivazione del materialismo dialettico in Francia*. Thèse de Doctorat. Université Paris-Sorbonne.
- Castelão-Lawless, T. (2004). Kuhn's Missed Opportunity and the Multifaceted Lives of Bachelard: Mythical, Institutional, Historical, Philosophical, Literary, Scientific. *Studies in the History and Philosophy of Science* 35:873–881.
- Cavaillès, J. (1938). *Remarques sur la formation de la théorie abstraite des ensembles*. Paris: Hermann.

- (1960). *Sur la logique et la théorie de la science*. 2nd ed. Paris: PUF.
- (1970). On Logic and the Theory of Science. In: *Phenomenology and the Natural Sciences*. Ed. by J. J. Kockelmans and T. J. Kiesel. Northwestern University Press.
- D'Amico, R. (1976). Review of Marxism and Epistemology: Bachelard, Canguilhem and Foucault by Dominique Lecourt. *The Journal of Modern History* 18:334–337.
- (1999). *Contemporary Continental Philosophy*. Boulder: Westview Press.
- Danny, L. (1999). *Historical and Constructivist Philosophies of Science: Kuhn, Bachelard and Canguilhem*. Hong Kong: University of Hong Kong Libraries.
- Ferrières, G. (1950). *Jean Cavaillès, philosophe et combattant 1903-1944*. Paris: Presses Universitaires de France. Cited from the 3rd ed., Ferrières 2003.
- (2000). *Jean Cavaillès: a philosopher in time of war, 1903-1944*. Lewiston, NY: Edwin Mellen Press. Tr. by T. N. F. Murtagh.
- (2003). *Jean Cavaillès: Un philosophe dans la guerre, 1903-1944*. Paris: Éditions du Félin.
- Foucault, M. (1978). Introduction. In: *On the Normal and the Pathological*. Ed. by G. Canguilhem. Dordrecht/Boston/London: Reidel, ix–xx.
- Ginestier, P. (1968). *La pensée de Bachelard. Collection pour connaître la pensée*. Paris: Bordas.
- Gouarné, I. (2010). *Philosoviétisme et Rationalisme moderne. L'introduction du marxisme dans les Sciences humaines en France (1920-1939)*. Thèse de Doctorat. Université de Nantes Faculté des Sciences Humaines.
- Gutting, G. (1990). Continental Philosophy and the History of Science. In: *Companion to the History of Modern Science*. Ed. by R. C. Olby, G. N. Cantor, J. R. R. Christie, and M. J. S. Hodges. London, New York: Routledge and Kegan Paul, 127–147.
- (2001). Appendix: Philosophy and the French Educational System. In: *French Philosophy in the Twentieth Century*. Cambridge: Cambridge University Press, 391–393.
- (2003). Thomas Kuhn and French Philosophy of Science. In: *Thomas Kuhn*. Ed. by T. Nickles. Cambridge: Cambridge University Press, 45–64.
- Halbwachs, F. (1972). Sur les problèmes de la Causalité physique. *Raison présente*:59–98.
- Jay, M. (1984). *Marxism and Totality*. Berkeley, Los Angeles, London: University of California Press.
- (1993). *Downcast Eyes: The Denigration of Vision in Twentieth-Century French Thought*. Los Angeles, London: University of California Press.
- Kockelmans, J. J. and T. J. Kiesel, eds. (1970). *Phenomenology and the Natural Sciences*. Northwestern University Press.
- Kuhn, T. S. (1970). Alexandre Koyré and the History of Science. *Encounter* 34:67–69.
- (2000). *The Road Since Structure: Philosophical Essays, 1970–1993, with an Autobiographical Interview*. Ed. by James Conant and John Haugeland. Chicago: The University of Chicago Press.
- Lakatos, I. and A. Musgrave, eds. (1970). *Criticism and the Growth of Knowledge*. Cambridge: Cambridge University Press.
- Larvor, B. (1998). *Lakatos: An Introduction*. London: Routledge.
- Lecourt, D. (1969). *L'Épistémologie historique de Gaston Bachelard*. Paris: Librairie philosophique J. Vrin.
- (1971). Avertissement. In: *Épistémologie. Textes choisis par Dominique Lecourt by G. Bachelard*. Presses Universitaires de France, 5–6.
- (1972). *L'Épistémologie historique de Gaston Bachelard*. 3. éd. Paris: Librairie philosophique J. Vrin.
- (1975). Introduction to the English Edition. In: *Marxism and Epistemology. Bachelard, Canguilhem and Foucault*. London: New Left Books, 7–19. tr. Ben Brewster.
- Lenin, V. (1909). *Materializm i empiriokrititsizm*. Moscow: Zveno Publishers.
- (1947). *Materialism and Empirio-Criticism*. Moscow: Foreign. Tr. by A Fineberg of Lenin 1909.

- Les Cahiers (1968). *Dialectique Marxiste et Pensée Structurale. Les Cahiers du Centre d'Études Socialistes special number 76–81, Feb-May 1968*.
- Martin, W. (1984). Editor's Introduction. In: *Bachelard, Science and Objectivity*. Ed. by M. Tiles. Cambridge: Cambridge University Press, 11–12.
- Méthot, P.-O. (2012). On the Genealogy of Concepts and Experimental Practices. Rethinking Gorges Canguilhem's Historical Epistemology. In: *Epistemology and History from Bachelard and Canguilhem to Today's History of Science*. Ed. by H. Schmidgen, P. Schöttler, and J.-F. Braunstein. MPIWG Preprint 434, 117–143.
- Montag, W. (2013). *Althusser and His Contemporaries: Philosophy's Perpetual War*. Durham: Duke University Press.
- Nickles, T. (2003). *Thomas Kuhn*. Cambridge: Cambridge University Press.
- Pannekoek, A. (1938). *Lenin als Philosoph*. Amsterdam: Bibliothek der "Ratekorrespondenz".
- (1975). *Lenin as Philosopher*. London: Merlin Press. Tr. by author of Pannekoek 1938.
- Pêcheux, M. and E. Balibar (1969). Définitions. In: *Sur l'Histoire des Sciences*. Ed. by M. Fichant and M. Pêcheux. Paris: Maspero, 8–12.
- Peden, K. (2014). *Spinoza Contra Phenomenology: French Rationalism from Cavallès to Deleuze. Cultural Memory in the Present*. Stanford: Stanford University Press.
- Raison présente* (1970). *Structuralisme et marxisme*. Paris: Union Générale d'Éditions.
- (1972). *Épistémologie et marxisme*. Paris: Union Générale d'Éditions.
- Rheinberger, H.-J. (2005). Gaston Bachelard and the Notion of "Phenomenotechnique." *Perspectives on Science*:313–328.
- Roy, J.-P. (1977). *Bachelard ou le concept contre l'image*. Montréal: Les Presses de l'Université.
- Salomon, J.-J. (1970). *Science et Politique*. Paris: Editions du Seuil.
- (1973). *Science and Politics*. London; Cambridge, Mass.: MacMillan Press; The MIT Press. tr. by Noël Lindsay of Salomon 1970.
- Schmidgen, H., P. Schöttler, and J.-F. Braunstein (2012). *Epistemology and History from Bachelard and Canguilhem to Today's History of Science*. MPIWG Preprint 434.
- Schmitt, A. (2002). *Der Perlentaucher und die fermenta cognitionis. Unterwegs zu einem 'neuen' Lessing*. URL: http://www.literaturkritik.de/public/rezension.php?rez_id=5232&ausgabe=200208.
- Schöttler, P. (2012). Sur la réception de l'"épistémologie française" en Allemagne. In: *Epistemology and History from Bachelard and Canguilhem to Today's History of Science*. MPIWG Preprint 434.
- Schuster, J. A. and G. Watchirs (1990). Natural Philosophy, Experiment and Discourse: Beyond the Kuhn/Bachelard Problematic. In: *Experimental Inquiries*. Ed. by H. E. LeGrand. Dordrecht: Reidel, 1–48.
- Sinaceur, H. (1994). *Jean Cavallès Philosophie mathématique*. Paris: Presses Universitaires de France.
- Smith, R. C. (1982). *Gaston Bachelard. Twayne World Authors Series 665*. Boston: Twayne Publishers.
- Solomon, J. (1945). M. Gaston Bachelard et le "nouvel esprit scientifique". *La Pensée* (2):47–55.
- Stachel, J. (1974). A Note on the Concept of Scientific Practice. In: *For Dirk Struik: Scientific, Historical and Political Essays in Honor of Dirk J. Struik*. Ed. by R.S. Cohen, J. Stachel, and M. W. Wartofsky. 15. Boston Studies in the Philosophy of Science, vol. 15. Boston: D. Reidel Publishing Company, 417–433.
- (1994). Scientific Discoveries as Historical Artifacts. In: *Trends in the Historiography of Science*. Ed. by K. Gavroglu, J. Christianidis, and E. Nicolaidis. Kluwer Academic Publishers, 139–148.
- (1995). Marx on Science and Capitalism. In: *Science, Politics and Social Practice*. Ed. by K. Gavroglu. Kluwer Academic Publishers, 69–85.

- (2003). Critical Realism: Bhaskar and Wartofsky. In: *Constructivism and Practice: Toward a Historical Epistemology*. Ed. by C. Gould. Lanham, Md: Rowman and Littlefield.
- (2012). Where is Knowledge? In: *Frontiers of Fundamental Physics: The Eleventh International Symposium*. Ed. by J. Kounieher, C. Barbachoux, T. Masson, and D. Vey. AIP Conference Proceedings, 404–426.
- Tasić, V. (2001). *Mathematics and the Roots of Postmodern Thought*. New York: Oxford University Press.
- Tiles, M. (1984). *Bachelard, Science and Objectivity*. Cambridge: Cambridge University Press.
- (2011). Is Historical Epistemology Part of the ‘Modernist Settlement’? *Erkenntnis* 75:525–543.