ANNALS OF SCIENCE, 59 (2002), 419–422

Essay Review

The Last Century of Physics

MARA BELLER, *Quantum Dialogue: The Making of a Revolution*. Chicago, IL, London: University of Chicago Press, 1999. xv+ 365 pp. US$35.00, ISBN 0-226-04181-6 (cloth); US$20.00, ISBN 0-226-04182-4 (paper).

HELGE KRAGH, *Quantum Generations: A History of Physics in the Twentieth Century*. Princeton, NJ: Princeton University Press, 1999. xiv+ 494 pp. US$35.00/£24.95, ISBN 0-691-01206-7 (cloth); US$18.95/£13.95, ISBN 0-691-09552-3 (paper).

Reviewed by

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How does a revolution transform into orthodoxy? How do brave challengers of the established order and taken-for-granted conventions end up privileged keepers of the new dogma, watchful of emerging sceptics and heretics? The riddle of this transformation—which is not so uncommon in history—inspires Mara Beller's inquiry into the history of the quantum revolution, arguably the most radical and important breakthrough in twentieth-century science. She follows the leaders of the quantum quest—in particular Albert Einstein, Niels Bohr, Max Born, Erwin Schrödinger, and Werner Heisenberg—in their attempts to design solutions for the deadly paradoxes that classical scientific logic and intuitions encountered on entering the microscopic domain of atoms and electrons. While technical and mathematical aspects are not left out of the picture, Beller's main concerns are philosophical, and her main target is the historical development of quantum philosophy in its once dominant form, the Copenhagen interpretation. Her analysis proceeds much further and deeper than most of the earlier ones, as she strives to understand not only the origins of the radically new line of thought, but also its 'consolidation', or the establishment of the general view that the found solution was final and the only possible one, which discouraged further inquiry and effectively ostracized those who dared to remain unconvinced.

Those familiar with Beller's earlier articles, where some of the book's ideas were first introduced, know that she is not at all enamoured of Heisenberg's uncertainty and Bohr's complementarity. Her sympathies lie with the minority of quantum physicists who continued to be doubtful, such as Einstein, Schrödinger, and David Bohm. Within the strict genre conventions of academic historical writing, her account tends to be on the passionate side. Emotions sometimes carry Beller's arguments too far, at least to my taste, but they also help her uncover what most previous philosophical analysts of the Copenhagen interpretation were unable or unwilling to see: internal contradictions, illogical turns, opportunistic trading of principles, and rhetorical tricks playing essential roles in the development of a supposedly consistent and comprehensive philosophical doctrine.

Annals of Science ISSN 0003-3790 print/ISSN 1464-505X online © 2002 Taylor & Francis Ltd
http://www.tandf.co.uk /journals
DOI: 10.1080/00033790110120490

Beller defines her historical methodology as 'dialogical', which is supposed to provide a better account for the 'fluid, open-ended', often haphazard flux of scientific creativity than more traditional philosophical reconstructions based on the notions of 'principles', 'commitments', rigid Kuhnian 'paradigms', or 'consensus' (pp. 2–3). In the dialogical approach, the main ideas of quantum philosophy emerge as situational and often inconsequential responses to momentary questions, criticisms and challenges. The story takes into account a wider variety of players in the intellectual game of quantum physics, many of whom did not become famous enough to be included in the traditional list of great thinkers and founding fathers of the discipline. At least as far as quantum history is concerned, the approach is well suited for the topic. There is hardly any other episode in twentieth-century science in which such a number of independent intellects and big egos—about a dozen 'great thinkers' alone—were simultaneously engaged in intensive communication, collaboration, and rivalry with each other while creating a landmark scientific achievement. Three years of this intellectual hype produced a great scientific revolution, quantum mechanics, an ideological doctrine, the Copenhagen interpretation, with accompanying heresies, and a not exactly fair distribution of credit. In hundreds of scientific papers, thousands of letters, and dozens of later reminiscences, the participants bequeathed the historian with multiple and incompatible accounts of events and positions taken. Personal relationships often mixed with conceptual stances, strongly held beliefs could be traded for crazy ideas, or otherwise entertained, abandoned, and changed like clothes, thus making 'logical reconstruction'—the favourite idol of historical philosophers—an utterly hopeless utopia.

Sorting out historical details and the twists and turns of this messy process is a daunting intellectual task. Although I sometimes find myself in strong disagreement with Beller's particular conclusions and jumps of logic, she succeeds with her general historical deconstruction, showing that '[t]he Copenhagen interpretation was erected not as a consistent philosophical framework, but as a collection of local responses to changing challengers from the opposition' (p. 167). Overall, the book contains a larger share of deep insights than is usual for our discipline, some of which are absolutely first class. Such as, for example, Beller's original observation that the earliest incarnation of quantum mechanics—matrix mechanics—rested on the philosophical assumption that the classical notions of space and time become invalid inside the atom. That idea did not survive long and was abandoned after the encounter with Schrödinger's wave mechanics and its intuitive pictures of atomic events. Contemporary physicists and philosophers are largely unaware of the attempt to throw away the microscopic geometry of space and time, since it hardly left visible footprints in the mature theory of quantum mechanics. Neither is the important philosophical victory by Schrödinger mentioned in the frequently used recollections by Bohr and Heisenberg. It takes a critical and insightful historian to uncover the short-lived radical proposal, which served as the midwife of quantum mechanics.

Among Beller's other important conclusions that run counter to traditional stories are the following: the clarification that during the decisive summer and autumn of 1926, Bohr was ready to accept Schrödinger's wave ontology, and that disagreements between them lay elsewhere; that at the same time Born was not yet philosophically committed to indeterminism and quite open to the idea of matter waves; that a textual analysis of both Heisenberg's indeterminacy paper and Bohr's complementarity argument of 1927 reveals hidden polemics and dialogues with several colleagues; that the criticism by Einstein, Podolsky, and Rosen forced Bohr

to abandon quietly one of his central interpretative claims about the uncontrolled disturbance effected by a measuring device upon a microscopic system. Any subsequent research on the topic will have to take these important findings into account.

'Although emotions ran high (or maybe because they did),'—writes Beller—'the dialogue that resulted produced significant contributions by all participants' (p. 74). In good fashion, her own work also fits the above description. Yet where the historian could have rested satisfied, the philosopher in Beller cannot refrain from throwing in many harsh judgements about the Copenhagen interpretation's 'confusions' and 'myths'. Understandable as a polemical reaction to several decades of uncritical hegemony, it may be less necessary now, when, as one would hope, there is at least tolerance for the plurality of different interpretations. Even if eventually superseded, the Copenhagen interpretation (or interpretations) will remain hanging on physics' wall of fame, along with Aristotle's four causes, Descartes' vortices, Newtonian action at a distance, and Einstein's principle of equivalence. I do wonder, however, together with Beller, why the confidence in the finality of the Copenhagen solution lasted so long, at least until the late 1960s, and why the conservatism of the late Bohr, Heisenberg, and their followers succeeded until now in discouraging all but a handful of intellectually courageous physicists from looking critically at the foundations of their discipline. The answer, at least partly, may be in the general dynamics of revolutionary and conservative tides in physics, which is one of the major themes of Helge Kragh's *Quantum Generations*.

Kragh's book is designed as a general survey of the history of physics in the twentieth century. Three roughly equal parts represent three unequal chronological periods, separated by the two world wars. The first, the 1890s to the 1910s, saw the discovery of the electron and of the theory of relativity, the physics of X-rays, radioactivity and other strange radiations, and the birth of an even stranger concept of the quantum. The second period included the completion of the quantum revolution and inquiries into the nature of nuclear particles, culminating in the man-made hell of Hiroshima. The third, from 1945 to the early 1990s, capitalized on earlier conceptual breakthroughs by building ever more gigantic accelerators to find new elementary particles, and inventing gadgets, such as transistors, lasers, computer chips, and communication devices. Some chapters of the book, in particular the later ones for which the existing historical literature is scantier, are based on Kragh's own research. He has published more and on a larger variety of topics within the history of twentieth-century physics than any other historian, and is thus uniquely qualified for the task. Those of us who have been teaching the subject and suffering from the lack of a textbook can now breathe easier, for *Quantum Generations* is an almost ideal learning tool for a professor, as well as for the reader with sufficient knowledge of physics. The text is extremely competent and balanced in structure, except for a few choices that struck me as peculiar. For example, the sequence of topics in the first part begins with the Bohr atom, followed by Planck's quantum, Einstein's relativity, and the electromagnetic worldview. Exactly the opposite order would have been more natural, both logically and chronologically. Also puzzling is the fact that the mainstream theory of the expanding Universe receives less attention in the book than the steady-state theory and the cosmological musings of Milne and Eddington.

Kragh's image of physics is not only about discovering facts and inventing theories. He also discusses examples of science gone astray: experimentalists seeing ghosts, such as various spurious rays, theorists speculating without brakes, and the

community as a whole making choices about right or wrong that in historical hindsight appear neither rational nor justified. Social and political aspects enter the story in the chapters on industrial research, physics in World War I, the crisis in Weimar Germany, nuclear weapons, the post-war marriage of science and militarism in the US, and the subsequent rise of anti-science critiques. Two recurrent themes pierce through the entire narrative. The first is the leitmotif of international rivalry: in Europe in the early decades, primarily between Germany and Great Britain, and between American and European physics towards the century's closure. Conspicuously left out of the picture is the Cold War rivalry of the mid-century, largely because of the book's single most important omitted topic: Soviet physics. Although a few Soviet names and results are mentioned in passing, only one issue—the conflict between Marxist philosophy and modern physics—is discussed in some detail. This particular issue, one has to say, was far more important for Cold War ideology and propaganda, than for the rise of Soviet physics and its impressive contributions, without discussing which any history of twentieth-century science would be incomplete.

The book's other structural theme is the tension between revolution and conservatism. It opens with a 1925 quote declaring the late nineteenth century 'an age of successful scientific orthodoxy, undisturbed by much thought beyond the conventions ... one of the dullest stages of thought since the time of the First Crusade' (p. 3). Exaggerated, as Kragh rightly mentions, the statement is, but its contempt is also very characteristic of the revolutionary mood and spirit of the early twentieth century. Equally exaggerated and characteristic of our own ultraconservative times is Kragh's downplaying of the earlier breakthroughs as 'conservative revolutions', because they did not change the nature of physics as physics, but 'only' (*sic*) the conceptual foundations of the discipline (pp. xiii, 447). It is precisely the willingness and the ability to challenge the most basic foundations of the existing intellectual order that distinguishes the first half of the twentieth century from the preceding period and also, as one can see now, from the century's conservative second half, which was more keen on consolidation, expansion, and aggrandizement, than on critical reassessments, overthrows, and new starts. The contrast is very explicit in physics, but it also holds for biology, as well as for other aspects of social and intellectual life.

The feeling of finality was especially strong in the 1990s, when it was hard even to think that future might become, in some fundamental sense, different from the present. One thus should not be too much surprised on reading Kragh's concluding remarks that '[a] large part of physics seems to be firmly stabilized. It becomes increasingly difficult to imagine that these parts, so thoroughly tested and so closely bound in a large network of theories and experiments, will change drastically in the future' (p. 450). There is a strong feeling of *déjà vu* here, for the mood returned a full circle to similar predictions made in the 1890s, to which Kragh refers in the beginning of his book and which proved so dramatically and unpredictably wrong. Do they have a chance to come true this time? The end of a particular discipline is certainly a more conceivable possibility than the general 'end of history'. If this happens, historians and philosophers, rather than scientists, will obtain a monopoly on sorting out the fundamental questions that posed such headaches to Einstein and Bohr. Like Egyptian sphinxes, the monument to the two great physicists, as shown on the dust cover of Beller's *Quantum Dialogue*, will forever remain the symbol of the ultimate secrets that nature persists in hiding from us, and the reminder to all future generations of the last great century of physics.