BOOK REVIEW[1]

Cushing, James T., *Philosophical Concepts in Physics. The Historical Relation Between Philosophy and Scientific Theories*, Cambridge University Press, 1998, xix + 424 pp.

This book successfully achieves to serve two different purposes. On the one hand, it is a readable physics-based introduction into the philosophy of science, written in an informal and accessible style. The author, himself a professor of physics at the University of Notre Dame and active in the philosophy of science for almost twenty years, carefully develops his metatheoretical arguments on a solid basis provided by an extensive survey along the lines of the historical development of physics. On the other hand, this book supplies one long argument for Cushing´s own attitude in the philosophy of science. While former studies of the author, from which this book draws in part, focused each on one special episode in the history of science, this book gathers case material from many different parts of physics and epochs. The main goal of this book is ”to impress upon the reader the essential and ineliminable role that philosophical considerations have played in the actual practice of science” (p. xv).

The book is beautifully edited and produced; it contains a wealth of illustrative figures, well-chosen short quotations from original sources and contemporary commentators (some longer quotations are relegated in an appendix at the end of a chapter) and does not dispense with insightful mathematical arguments in the main text (some advanced deductions are, however, relegated in the appendices). It contains nine parts, whereas only the first and the last one are exclusively devoted to philosophical issues. The seven remaining parts, each subdivided into three chapters, centre around one major episode (a theory, a world view, etc.) in the history of physics. The author presents this material in a clear and philosophically unbiased way so that also readers who do not share Cushing's subsequent philosophical conclusions will find this inspiring book extremely useful.

Part 1 (”The scientific enterprise”) discusses some traditional (”objectivist”) views concerning the status of scientific knowledge, ”the” scientific method, and the relation

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between metaphysics and science. In this context, the relevant work of Aristotle, F. Bacon, R. Descartes, D. Hume, and - as a representative of our century - K. Popper is examined and several methodological strategies (such as inductivism, the hypothetico-deductive method, and falsificationism) are introduced. All of these strategies seem to play *some* role in the actual practice of science.

Part 2 (”Ancient and modern models of the universe”) gives a careful account of some early Greek cosmological considerations and of the Ptolemaic and Copernican model of the universe in the light of the observational evidence of that time. Furthermore the once highly influential ”impetus theory” and Galileis theory of motion is discussed. Cushing shows in detail why Galilei could never have performed his famous Leaning Tower of Pisa experiment. This is one of several examples where Cushing points out wrong accounts of the history of physics in many physics textbooks. Other examples for this phenomenon, to be discussed in later chapters, are Planck’s work on the black body radiation, Bohrs’s original way to his atomic model, and Maxwell’s actual reasoning that lead him to postulate the existence of the displacement current.

Part 3 (”The Newtonian universe”) introduces some of the arguments I. Newton’s develops in his influential treatise *Principia*. Cushing explains in detail what role Kepler’s laws played for the construction of Newton’s theory and, as an illustration, how the ocean tides can be explained with this theory.

Part 4 (”A perspective”) presents the world view of Newtonian physics, elaborated by Newton’s successors. Special emphasis is given to an analysis of the concept of determinism. Cushing shows how this concept emerged from a bold extrapolation of an investigation of a few special force functions and the application of perturbation theory for many body systems. Since modern chaos theory established that determinism does not imply predictability, Cushing suggests that there is no way to decide if classical systems are deterministic or indeterministic. This interesting thought, of course, presupposes Cushing’s empiricist assumption that such decisions can only be made on the basis of observations. This part also contains an informative discussion of the well-known dispute between G. Galilei and the church. Cushing points out what role evidence as well as the different characters of the relevant *dramatis personae* and other social factors played in this conflict.

Part 5 (”Mechanical versus electrodynamical world views”) presents a challenge for the world view associated with Newtonian physics. Cushing discusses various mechanical models of the electromagnetic aether and Maxwell’s theory. This part also contains an illuminating analysis of data on the variation of the electron mass with velocity in the light of rival theories of the electron obtained in experiments performed by W. Kaufmann in the first decade of this century. Cushing shows in detail how the hypotheses in question are embedded in a web of background assumptions and concludes that ”the Kaufmann experiment [...] did not act as a definitive and deciding (`crucial´) experiment in the sense that a strict falsificationist view of science would lead one to expect” (p. 220). This kind of argument is a general feature of this book. Cushing establishes that a certain position in the philosophy of science that is essentially a result of logical considerations does not agree with the actual practice of science. Unfortunately, Cushing often presents only dummy positions that no one holds any more (such as ”strict” falsificationism (p. 366) or certain criteria of confirmation (p. 369)). G. Andersson, for example, shows in his vigorous defence of falsificationism that episodes like the analysis of the Kaufmann experiment fit well in this metatheoretical scheme (see G. Andersson, <English title etc.>, sec. 8.2).

Part 6 (”The theory of relativity”) gives an overview of Einstein’s special and general theory of relativity. At the end of the chapter Cushing presents a world view based on general relativity. Quite surprisingly, Cushing missed to mention in this context the current discussion of determinism in general relativity and the recurrent theme of the underdetermination of geometry by evidence. A discussion of these issues could have supplemented his respective views developed in part 8.

Part 7 (”The quantum world and the completeness of quantum mechanics”) provides an account of the development of quantum mechanics and a careful analysis of the role of the famous inequalities first derived by J. Bell. Furthermore, this part contains a lucid exposition of the measurement problem, the single big problem for many interpreters of quantum mechanics, and a reconstruction of the famous debate between N. Bohr and A. Einstein.

Part 8 (”Some philosophical lessons from quantum mechanics”) continues the discussion of quantum mechanics with an analysis of the EPR paper and the exposition of an alternative to the standard (”Copenhagen”) interpretation of quantum mechanics. This alternative interpretation, first suggested by D. Bohm in 1952, supports a radically different ontology while, according to the author, being empirically indistinguishable from the standard version. More specifically, Cushing argues that the Bohm theory uses the same *formalism* as the Copenhagen theory, but differs in the *interpretation* of this formalism. From this several conclusions are drawn. Firstly, ”the best theory we have” is underdetermined by data. Secondly, this situation implies that on the basis of observation alone, the choice between determinism and indeterminism cannot be decided conclusively. Thirdly, this diagnosis raises a serious problem for the scientific realist, since observation does not rule out one of two ontologically quite different theories. If one accepts Cushing's exposition, one may nevertheless wonder, if there aren't any other (”soft”) criteria to identify the ”true” theory. We shall come back to the role and status Cushing attributes to them later. One may, however, also doubt that both ”interpretations” (cf. M. Jammer's usage of this term) are indeed empirically indistinguishable. After all, Bohm's theory has an additional equation of motion for the particles' trajectories that may eventually produce new empirical consequences. In this case, Cushing would have lost his main argument for actual underdetermination in science and against scientific realism. It should be noted, however, that Cushing does not primarily intend to defend an elaborated philosophical position in this book. Nevertheless, several positive claims can be identified (see Part 9):

1. Science is a ”coupled network” of practice, methods, and goals. None of these levels is immune to change, ”either in principle or in fact” (372 f). This means, for example, that there is no fixed methodology (such as Popper's). In fact, scientists happen to be opportunists; in order to solve scientific problems they are willing to provisionally accept any philosophical (or whatsoever) position or methodology that might help.
2. The development of scientific theories is, like any other cultural activity, accompanied by the occurrence of historically contingent factors. By telling a fascinating story of counterfactual history, Cushing shows that the development of modern physical theory (quantum theory) could well have developed quite differently. This demonstrates that (at least one) important scientific theory is in fact underdetermined by data.
3. In order to select one theory over another, scientists have to apply soft criteria, such as simplicity. These criteria, however, have some uneliminable subjective component and are therefore not suited to identify the ”true” theory. The only real criteria are the ”hard” ones: empirical adequacy and logical consistency. But they do not uniquely determine the wanted theory.

Another important weak criterion for theory selection is understandability. This concept is notoriously hard to explicate. Cushing criticises the `standard view´ that understanding can be equated with unification or reduction. He maintains that understanding has also something to do with visualizability and the existence of a causal story. The discussion of the EPR-correlations shows that scientists are not completely satisfied with theories that are empirically adequate and provide formal explanations, but do not produce any real understanding whatsoever. The Copenhagen-Bohm case shows, however, that understandable theories (such as the Bohm theory) are not always preferred.

At least as noticeable as these positive claims is way of doing philosophy of science Cushing implicitly suggests and demonstrates in this book. The author supports a naturalistic and interdisciplinary approach to science, history, and philosophy (”it takes a lot of history of science to anchor even a little philosophy of science” (xv)). He points out, for example, that it does not suffice to restrict oneself to the business of reconstructing already successful theories (”Whig-history”). Philosophers of science have to go beyond the textbook level and examine the whole (philosophical, historical, sociological, etc.) culture in which theories are constructed. This approach is descriptive, not prescriptive. Cushing has shown that it nevertheless leads to interesting insights. For good reasons Cushing does not provide another overall philosophical account of science, but he does a lot to increase our understanding of what science is and how it really functions.

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