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OBITUARY

The Philosopher of the Physicists: The Legacy of Erhard Scheibe

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I

Erhard Scheibe was born in Berlin on September 24, 1927, a few days after the physicist Niels Bohr gave the famous "Como" lecture which sparked the Bohr-Einstein debate on the nature of quantum mechanics. This was something of an omen, for philosophical problems concerning the relations between quantum mechanics and classical physics stood in the centre of Scheibe's work throughout his life.

The family home did not guide him in this direction. Erhard was the only child of Albert Scheibe and Maria, née Heidenreich, and grew up in an upper middle-class ambience marked by discipline and subtle taste. His father, a former naval officer, became a business man after 1918, and contributed a preface to the 1937 edition of Admiral Scheer's book on the German armada in the First World War. Erhard's uncle on the father's side was the sculptor Richard Scheibe, a member of the Berlin Secession, who taught at Berlin University of the Arts from the mid 1930s. Gerhard Marcks, one of Richard Scheibe's friends, made a portrait sculpture of the father Albert.

The adolescent Scheibe belonged to that small group of German youth who were forced to adulthood early, and yet largely escaped the utter destruction brought about by the course of the Second World War. Erhard attended the Mommsen Gymnasium in Berlin-Charlottenburg until the age of fifteen, when he became a Flakhelfer, an anti-aircraft auxiliary. From the autumn of 1944 until the spring of 1945, he managed to avoid the military draft by continually changing his residence. He used to recount that in the summer after the end of the Second World War, he read Kant's Critique of Pure Reason, giving rise to a feeling of vertigo which stayed with him for the rest of his life.

He finished his secondary school education in Singen/Hohentwiel, in south-west Germany, receiving his university entrance diploma. In 1946, he began his studies in Göttingen, concentrating on mathematics, physics and philosophy. He soon belonged to the circle of young scholars around Werner Heisenberg and Carl-Friedrich von

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Weizsäcker. In 1952, he met his future wife, Maria Elgert-Eggers, at that time still a schoolgirl, giving her private lessons in mathematics and physics, and also playing four-handed piano with her. He received his doctorate with a thesis in mathematics (1955), obtained a fellowship at the Max Planck Institute for Physics in Göttingen, working with Heisenberg, and then, 2 years later, proceeded to Hamburg as von Weizsäcker's assistant. In 1958, he and Maria married. Within a few years, they had three children, and from this point on, Erhard Scheibe's personal life was as unspectacular as his academic career became outstanding.

II

Scheibe obtained his Habilitation in 1963 in Hamburg with a philosophical study of quantum mechanics. His inaugural lecture on the philosophy of Plato was accepted by the renowned journal for ancient philosophy, Phronesis (1967a), demonstrating even at this early stage his remarkable philosophical range.

The Habilitation Thesis, entitled *Die kontingenten Aussagen in der Physik* [The Contingent Propositions of Physics], was published a year later (1964) with a preface by von Weizsäcker. The 'contingent' propositions of physical theories are the statements about physical systems which are not fixed by the laws of physics—in particular, initial values, boundary conditions, etc. By focusing on them, the book elucidates the similarities and distinctions between the classical and the quantum descriptions of a single physical system. This approach is in contrast to the various attempts at formulating a 'quantum logic', which were initiated by Johann von Neumann and Garrett Birkhoff in the 1930s and further elaborated by Peter Mittelstaedt in von Weizsäcker's circle. Scheibe's approach aims to show how quantum theory may safely be established on the grounds of classical logic, with recourse to the Copenhagen interpretation of quantum theory, but without any need of quantum logic. The approach follows Bohr's lines of thought, according to which the language of classical physics and the structure of quantum theory are in a certain sense complementary. Scheibe interprets the relation between classical and quantum concepts in epistemological terms, emphasizing that quantum theory cannot be understood without classical physics, while on the other hand quantum theory also contributes to a better understanding of the foundations of classical physics.

Methodologically, the book follows the mathematical concept of a theory structure developed by Günter Ludwig along the lines set out by von Neumann. This is in decided contrast to von Weizsäcker's much more informal philosophical work. Scheibe's life-long project was to bring as much mathematical clarity as possible into the philosophy of physics, and in particular, into the conceptual incompatibilities in the foundations of physics. A basic conceptual distinction from 1964 concerns the structure and the evolution or behavior of a physical system. This distinction gives rise to the following trisection of the propositions of a system into:

(1) (nomological) propositions about structure, which describe the state space;
(2) nomological propositions about behavior, which describe the dynamic evolution;
(3) contingent propositions about behavior, which describe the actual physical state.

The main differences between quantum theory and the theories of classical physics are reflected in the contingent propositions, as the book shows in great detail. This is closely related to the point that classical theories are deterministic whereas quantum theory is not.

The quantum indeterminism is due to a specific epistemic character of the contingent propositions in quantum theory. And it is just this specific epistemic character which allows us to avoid quantum logic. Indeed, the main result of the book is that there are only two options for interpreting the standard version of quantum theory: either an 'ontological' version of the theory built on the foundation of non-classical quantum logic, or an 'epistemic' version, built this time on classical logic.

In 1964, as well as publishing this influential book, Scheibe also received a call to Göttingen as a full Professor of Philosophy. Three years later, he turned down a call which would have taken him back to Hamburg. Instead, he and his family would remain in Göttingen for 18 years, where he occupied himself above all with the structure of physical theories.

In the first decade of this period, he published *The Logical Analysis of Quantum Mechanics* (1973). The book continues the project of the Habilitation Thesis, that is, to reconstruct quantum theory and to compare it to classical mechanics. Its main task is to clarify what has been called the 'Copenhagen interpretation' or 'orthodox' version of quantum theory. The introduction stresses how difficult this task turned out to be, given that the quantum 'orthodoxy' emerged in several versions from the work of Bohr, Heisenberg, von Neumann, Wolfgang Pauli, and others. Bohr's informal approach, which did not give rise to any rigorous version of quantum mechanics, differs substantially from the mathematical approaches of Heisenberg and von Neumann. Scheibe emphasizes that reconstructing the content of the latter in axiomatic terms does not give rise to a single unified theory either (1973, 5). For this reason, he took the decision to reconstruct only the most important fragments of quantum theory as well as their counterparts in classical mechanics and classical statistical mechanics.

The book begins with a crystal clear presentation of Bohr's philosophy of 'complementarity'. Here, the aim is to clarify the arguments that underlie Bohr's various definitions of complementarity and the development of his thought over the two decades of the Bohr-Einstein debate. The remaining chapters give axiomatic reconstructions of quantum mechanics in Hilbert space in terms of quantities (or observables) and in terms of algebraic properties; the deterministic and indeterministic features of classical and quantum mechanics; the von Neumann programme; the reduction of states and the measurement process; and the problem of "hidden parameters". The book ends with a formal analysis of the thought experiment of Einstein, Podolsky and Rosen (EPR), the high point of the Bohr-Einstein debate. In search of logical clarity, Scheibe analyses the reality criterion and the completeness conditions of the EPR paper by way of an extension of ordinary quantum mechanics that gives rise to a logical contradiction.

Edward MacKinnon's detailed review emphasizes that the book, "essentially a defense of the adequacy and logical consistency of the orthodox Copenhagen interpretation of quantum mechanics, sets a new standard for rigorous logical analysis of this difficult topic" (MacKinnon 1975, 96). In fact, the book shows that there is no easy route to the establishment of the unity of physics. On the one hand, there is the gap between the classical theories and quantum mechanics. On the other hand, even the attempt to give a logically rigorous formulation of 'the' quantum theory behind the standard textbook accounts ends up in a variety of axiomatic fragments that can by no means be unified in a simple way. In the following decades, Scheibe would be engaged with just this apparent fragmentation of physical theory, and what it means for the unity of physics. With his patient efforts to work out how, despite this, unity might nevertheless be established, he pursued the life-long goal of his teacher, von Weizsäcker.[1]

[1] Von Weizsäcker died in 2007. See the obituary (Drieschner 2008) and the bibliography (Anacker and Schöttler 2008).

III

In addition to the books, there were numerous lectures and essays covering themes from the concept of cause to scientific explanation, from Leibniz to Kant, from the laws of physics to the laws of nature, from the structure of physical theories to the progress of physics, not to mention the many technical articles on quantum mechanics and special or general relativity. Scheibe's reputation grew. He became, not just one of the most important philosophers of the exact sciences, but the one who shaped the philosophy of physics in the German speaking world. In 1975, he joined the Editorial Board of this journal. In 1977, he became a full member of the Academy of the Sciences of Göttingen. In the academic year 1979–1980, he was a fellow at the Center for Interdisciplinary Research (ZIF) at Bielefeld and at the Center for Philosophy of Science in Pittsburgh. In 1982, he became a corresponding member of the Academy of Science and Letters of Mainz, and of the Académie Internationale de la Philosophie des Sciences in Brussels.

From 1982 until his retirement and nomination as Emeritus Professor in 1992, Scheibe was the holder of a then newly-founded Chair of Philosophy at Heidelberg, one dedicated to philosophical issues concerning the formal and natural sciences. His move to Heidelberg marked a shift in his interests from the formal structure of physical theories to more general features of the philosophy of physics. Once established in Heidelberg, he turned his attention more to the historical and conceptual background of physics, including the ways in which physics is rooted in the traditions of rationalism and empiricism. The shift of interest was in particular marked by the topic of his inaugural lecture *Kohärenz und Kontingenz. Die Einheit der Physik und die rationalistische Tradition* [Coherence and Contingency. The Unity of Physics and the Tradition of Rationalism] (1986c). In both research and teaching, he sought to investigate the characteristic ways the physics of the 20th century had combined both traditions. In early 1987 he spent 3 months as an invited professor at the University of California in Irvine. In the academic year 1987/1988 he was a fellow at the Wissenschaftskolleg [Institute for Advanced Studies] in Berlin. In 1988, he held the Presidency of the Leibniz Committee of the Academy in Göttingen. From 1989 to 2002, he was a member of the Editorial Board of the journal *Philosophia Naturalis*.

In addition to his outstanding work on the axiomatic foundations and the philosophical background of modern physics, Erhard Scheibe was an influential academic teacher. He exuded a unique combination of scientific rigor and precision, combined with warmth and friendship, a combination which embraced and inspired both his students and the Humboldt Fellows and other scientific guests from all over the world who came to work with him. In the first decade of the Göttingen years, he supervised the Habilitation of Lorenz Krüger, who later became a full professor in Bielefeld and Göttingen, and, in the years before his untimely death, founded the Max Planck Institute for the History of Science in Berlin. Other by now well-established students and *Assistenten* from the Göttingen or Heidelberg years were Werner Diederich, Andreas Hüttemann, Bernd-Olaf Küppers, Ulrich Majer, and Manfred Stöckler, as well as the author of this article.

But even though many of them were, in time, appointed to chairs in philosophy of science at German universities, there was never a 'Scheibe school' as such, and Scheibe was not the least bit interested in the indoctrination of anyone. Indeed, owing to his modest nature, his respect for the individual approaches of others, and also his need for solitary work in view of the difficulties of his projects, Scheibe has no direct followers. Having the highest esteem for scientific objectivity, he considered himself to be a 'Diener der Wissenschaft', a true servant of science. His reference group was made up from colleagues in physics and mathematics, with whom he was involved in many discussions. In

particular, he maintained an extensive correspondence on the foundations of quantum mechanics with Günter Ludwig and Hans Dieter Zeh.

The lack of a 'Scheibe school' stood in striking contrast to the 'Erlangen' and 'Stegmüller' schools of that time. Scheibe repeatedly debated with the members of the latter, in particular Carlos-Ulises Moulines, over the formal tools to be employed in reconstructing the architectonics of physics. Outside the German speaking world, Scheibe was, perhaps, not as well-known to the general public as the significance and depth of his work merited. But he was renowned among experts, a fact which is testified by the frequency with which he was invited to international conferences, and also by the number of young scholars who came to study with him under the auspices of the Humboldt Stiftung.

It is a sign of Scheibe's engagement as a teacher, but possibly also of the worsening situation as regards German university research, that he was able to complete his central work only with the freedom which retirement brings. After his retirement in 1992, he and Maria moved back to Hamburg. The book *Die Reduktion physikalischer Theorien. Ein Beitrag zur Einheit der Physik* [The Reduction of Physical Theories. A Contribution to the Unity of Physics] appeared in two volumes in 1997 and 1999. It is a monumental investigation of the unity of physics in the face of apparently incommensurable theories. Whoever wants to profit from a study of this should have a sound background knowledge of the mathematical and logical foundations of modern theoretical physics. Springer is currently preparing an English translation of this seminal work.

Bearing as it does the fruits of Scheibe's profound work on the axiomatic foundations of physics, the book is his answer to the philosophical discussion surrounding incommensurability. From his insights into the axiomatic fragments of physical theories, he knew that the unity of physics is not available in any cheap or easy way, and he explained it in terms of inter-theoretic relations. This approach gave rise to a completely novel account of reduction and to a new understanding of what progress in physics amounts to. The crucial new idea is that there is no unique way to reduce one physical theory to another, but (in general) many. These have to be spelled out in terms of different kinds of inter-theoretic reduction relations, in particular, various kinds of exact reduction (equivalence, embedding, refinement, extension, unification), approximate reduction and partial reduction. Scheibe emphasizes that, in contradistinction to all previous work on reduction, his new approach is "synthetic" or "recursive"; it is not centered around a general pre-determined concept of theory reduction, but rather aims at finding several non-decomposable, or elementary, kinds of reduction which are as specific as possible (1997, 3–4). The resulting concepts of reduction and of unity are constructive, multi-faceted, and open to extensions.

IV

The first volume of *Die Reduktion physikalischer Theorien* (1997) develops the theory. The second volume (1999) applies it in extensive case studies to the conceptual caesura within the foundations of current physics. Since the virtues and the main results of these investigations have been the subject of several detailed reviews (Bartelborth 1999; Diederich 1999; Falkenburg 1997; Hüttemann 2000a, b; Stöckler 1997), here it is perhaps of more interest to sketch how their topics are interwoven with the rest of Scheibe's work, in particular with the numerous articles which emerged from Scheibe's years in Göttingen and Heidelberg.

The inter-theoretic relations between classical mechanics, classical statistical mechanics, and quantum theory puzzled Scheibe for many years, beginning with the first two

books (1964, 1973). From 1973 on, he took up the topic of theory reduction explicitly, in concrete case studies (1973c, 1981b, 1988h, 1997d), in articles on approximate explanation (1973e), the comparison of theories (1975, 1976a, 1976d, 1982b, 1986b), and the explanation of one theory by another (1976b, 1976e). From 1984 on, he linked these topics to the problem of progress in physics (1984b), deepening the latter in subsequent articles (1985a, c). The last-mentioned articles lay the foundation for the first chapter of *Die Reduktion*, which discusses the physicists' and the philosophers' views about theoretical progress (1997, 13–34). These views indeed turn out to be much more subtle than is generally allowed for within the philosophy of science: the progress of physics does not preclude there being some highly significant conceptual breaks; scientific revolutions do not preclude the existence of some standards for the comparison of theories; and, on a closer look, neither the physicists nor the philosophers deny this.

The detailed formal explanations of the book are based on a series of articles on the structure of physical theories, the different ways of reconstructing them, and the relation between mathematics and the axiomatic approach to physics (1979, 1981c, 1982a, 1983b, 1986a, 1988c). They compare Ludwig's approach to that of the 'Stegmüller' school, which in turn is based on the model-theoretic approach of Joseph D. Sneed, and they begin to shape the way in which Scheibe's own views differ. He insists on a distinction between mathematical and physical concepts, which is not taken into account by the empiricist distinction of observables and unobservables. According to the second chapter of *Die Reduktion*, the structure of a physical theory indeed rests on three kind of objects, namely mathematical, physical, and mixed objects (1997, 63–75). To the physical objects belong in particular 'theoretical entities' such as the strength of an electromagnetic field. And this feature shows that Scheibe's approach lies somewhere in between rationalism and empiricism, just as does 'the' philosophy of the physicists which he started to investigate in a systematic way in Heidelberg (See the books 2001 and 2006/2007).

Some of the earlier articles indicate in addition that the resulting theory of reduction would deal with various different kinds of inter-theoretic relations, such as approximative explanation (1973e), different types of successor relations between theories (1983a), and the distinction between equivalence and reduction (1988h). But the many different variants of exact, approximate, and partial reduction discussed in chapters IV-VI of *Die Reduktion*, and the many challenging cases provided by the theories of relativity, the notion of micro-reduction, and the reduction of classical to quantum cases set out in chapters VII–X (1999), could only be worked out in detail after Scheibe's retirement.

Let me conclude my remarks on *Die Reduktion* with a look at some philosophical aspects of the unity of physics advanced there. How does it relate to traditional views? For most physicists, the unity of physics is a heuristic principle of theory construction which is based on faith in a corresponding structural unity of nature. Newton, Maxwell, and Einstein used this principle in order to construct more and more comprehensive theories. Planck explained the unity of physics in the rationalist, if not Platonist, terms of an all-embracing mathematical structure behind the phenomena, sketching a 20th century version of Galileo's dignified book of nature (Planck 1909). In contrast to this rationalist faith, Kant stressed in the *Critique of Judgment* that the idea of unity of nature does not have any certain foundation in the objective structure of the phenomena. According to him, the unity of nature is nothing but a regulative principle which governs our own search for systematic, conceptually unified knowledge.

Following Kant and Bohr, Scheibe's teacher von Weizsäcker had tried to bridge both views in a 'neo-transcendental' approach to physics, and to the Copenhagen interpretation of quantum theory in particular. On the occasion of von Weizsäcker's 80th birthday,

Scheibe discussed this approach and its relation to the goal of a 'final' theory of physics. According to von Weizsäcker, such a final theory of physics should no longer be built on empirical laws but only on the conditions of possible experience (1993c). In his discussion, Scheibe emphasizes that this 'neo-transcendental' approach comes along with an extreme reductionism, which, however, in some aspects comes close to Thomas S. Kuhn's or Paul Feyerabend's views about theory change.

The article appeared in the same year as the first sketch of the new theory of reduction (1993d). This theory and the resulting many-faceted account of the unity of physics is in sharp contrast to von Weizsäcker's 'neo-transcendental' approach, but it, too, bridges the gap between the traditional views mentioned above. Scheibe's unity of physics is 'synthetic' or constructive, just as Kant had suggested. However, it is not a priori, as von Weizsäcker had assumed, but constructed from the empirical laws of physics. At the same time, this unity of physics is rational; it rests on the structure of the phenomena, just as the founders of modern physics had claimed. But it differs substantially from the rationalist idea of an all-embracing, 'final' theory of physics. It is made up of many axiomatic fragments, which are linked by many kinds of inter-theoretical relations. According to Scheibe, the unity of physics is piecemeal, though it is surely not piecemeal in Nancy Cartwright's understanding of that term.

In a certain sense, Scheibe's approach stands in the long-neglected Neo-Kantian tradition of philosophy of science, which was established by the 'Marburg' school of Hermann Cohen, Paul Natorp, and Ernst Cassirer. The affinity lies mainly in one feature. It was Natorp who first emphasized that physical reality is "nicht gegeben, sondern aufgegeben", that is, not given but posed for us as a problem, a problem which has to be resolved by construction.[2] And it was Einstein who took up this phrase (in the reply to his critics in the 1949 book Einstein—Philosopher—Scientist edited by Paul A. Schilpp), by commenting that he was late in coming to appreciate Kant's philosophy.[3] Scheibe surely knew the latter source, but perhaps not the former. He would probably have listed the Neo-Kantians among the defenders of apriorism, like Kant himself and von Weizsäcker.

The constructivist aspects of the Neo-Kantian approach are not to be confused with more recent versions of constructivism. In his article "Mißverstandene Naturwissenschaft [Science Misunderstood]" (1997b), Scheibe sharply criticizes several recent constructivist views, such as the 'Erlangen' school, the radical constructivism advanced by neuroscientists such as Heinz von Foerster, or the 'social constructivism' propagated by Andrew Pickering from the 'Edinburgh' school, Bruno Latour, and other post-modern thinkers. These views differ substantially from the Neo-Kantian'constructivist' approaches, among which, I would suggest, we place Scheibe's theory of reduction. The common ground of Scheibe's and Natorp's views is the insight that the unity of physics, and with it our concept of physical reality, is still under construction, and will perhaps forever be.

[2] Natorp (1921, 18): „So kann also von keinem ‚gegebenen' Gegenstand mehr die Rede sein; also auch nicht von Erkenntnis als bloßer Analyse dieses Gegebenen. Gerade der Gegenstand vielmehr ist *Aufgabe*, ist *Problem* ins Unendliche."Matters that are „gegeben", i.e., given, or „aufgegeben", i.e., posed as problems, were the starting points of the traditional 'analytic' and 'synthetic' methods respectively. These were based on ancient geometry, used by the rationalist philosophers in their accounts of an ars inveniendi, and were still well-known to the Neo-Kantian philosophers around 1900. Scheibe discussed these methods in his Heidelberg seminars on the classical texts of rationalism.

[3] See Einstein (1949, 680): "I did not grow up in the Kantian tradition, but came to understand the truly valuable which is to be found in his doctrine, alongside of errors which today are quite obvious, only quite late. It is contained in the sentence: 'The real is not given to us, but put to us (aufgegeben) (by way of a riddle)'".

V

A collection in English of Scheibe's most important papers and lectures followed, making a great deal more of his work accessible to the English speaking philosophical world. *Between Rationalism and Empiricism: Selected Papers in the Philosophy of Physics* (2001) has eight parts. Each of them is preceded by a brief introduction by the author. The first part, 'Between Rationalism and Empiricism', is programmatic, as is, in a sense, the whole book. It deals with the sophisticated philosophical attitudes of the most prominent physicists, "wavering" as it were between these two philosophical extremes. Scheibe points out that these extremes themselves do not help to understand the structure of physics. It is worth quoting a lengthy passage from the introduction, which makes explicit the core of his philosophical convictions:

"Einstein has gone so far as to call the physicist an 'unscrupulous opportunist' who, depending on the circumstances, appears as a realist or an idealist or a positivist or even a Platonist […]. But this wavering attitude is by no means the product of opportunism. Rather it should be viewed as protest against exaggerated positions of philosophers of science which bring their inventors repute and even fame but lead them astray from the road of to truth. […] But whoever sets out […] to look for a workable synthesis is not an opportunist. He is not even an eclecticist in the pejorative sense of the word which we have in mind whenever we take the extreme positions to be the genuine ones. This is not justified if every attempt at their application to a further developed science fails. We have to turn the tables and view our sciences as the empirical material for an appropriate theory of scientific knowledge. A thoroughgoing analysis has to be started before one comes to generalizations" (Scheibe 2001, 1).

Here we see the deepest reason for the fact that there is no 'Scheibe school'. According to Scheibe, the only task of the philosophy of science is to analyze the structure of scientific theories, the ways in which they relate to each other, the reasons which led their creators to establish them, and the views of the scientists about the way in which the theories express physical reality. Any philosophical doctrine that might give rise to a school would be contrary to this spirit. It follows that Scheibe was much more inclined to give support to students who were investigating philosophical problems connected to actual scientific practice, as opposed to investigating what he used to call the 'self-generated problems of philosophy of science'.

For the same reason, he was increasingly convinced that the structure and the conceptual revolutions of physics can be properly understood only by combining historical and systematical studies. This is clearly seen from the choice of articles he selected for inclusion in the volume. Part I of the collection is centered around a paper on Kant's apriorism (1988e), the article on Weizsäcker's 'neo-transcendental' approach mentioned above (1993c), and the evening lecture from the Stuttgarter Hegel-Kongress 1993 (1994d), whose title is given to both the collection as well as its first section.

Part II of the collection, entitled 'The Philosophy of the Physicists', contains papers that lay the foundation for the project from which Scheibe's last book (2006) emerged. The article on the physicists' conception of progress (1988a) overlaps with the first chapter of *Die Reduktion physikalischer Theorien*. The paper on Einstein's epistemology (1992b), given in Heidelberg as his farewell lecture, explains the details of Einstein's "wavering attitude" between rationalism and empiricism. The investigation of Heisenberg's concept of a closed theory (1993a), in turn, is related to Scheibe's specific approach to reconstructing the structure of physical theories.

The papers of Part III of the collection, entitled 'Reconstruction', defend the enterprise of a 'rational' reconstruction of physical theories (1984a, 1988f). This notion was in particular attacked by Feyerabend, and there is a sense in which it might be seen to be in conflict with the ideal of focusing on the practice of physics. In addition, the papers here demonstrate the ways in which Scheibe's approach differs from Ludwig's or Sneed's (1979, 1981c, 1982a).

Part IV of the collection ('Laws of Nature') contains articles that extend the ideas on coherence and contingency (1989a), first presented in the inaugural lecture given in Heidelberg in 1982, to observations about physical laws and the way to express them (1991a), the reference of quantum mechanics to physical systems (1991f), a tension between the generality of laws and the uniqueness of the universe (1991b), and the limitations of knowledge which may arise from these problems (1998a). This section stands on its own, not only in Scheibe's work, but also in the philosophy of science in general. According to the review by Maarten Van Dyck, it takes up the "perennial question about Laws of Nature" in terms of the "tension that exists between on the one hand and their content, which […] concerns individual systems, and on the other hand their form, which (in) famously is to be universal", a tension which is closely related to the "basic opposition between empiricism and rationalism".[4] But the question remains of what exactly this means for the validity of physical laws and the claims of scientific realism.

The ideas underlying these articles may have been influenced by many years of discussions with Nancy Cartwright. He first met her at the ZIF in Bielefeld, then at the Wissenschaftskolleg in Berlin, and at many conferences. The common elements between Erhard and Nancy were the convictions that the best strategy in philosophy of science is to study scientific practice, that the structure of physics is piecemeal, and that this fragmentary structure is closely related to certain limitations of our physical knowledge. The point of departure between them was the question of whether it is worthwhile to make the effort to give a rational reconstruction of the axiomatic fragments and their inter-theoretic relations.

The other parts of Scheibe's collection put together further articles on the topics of Scheibe's books. Part V ('Reduction'), contains several of the papers mentioned in the last section. Part VI ('Foundations of Quantum Mechanics') incorporates a more popular paper on the Copenhagen interpretation (1990a) and five highly technical papers on quantum logic, hidden variables, EPR, and Bell's theorems published between 1985 and 1993. Part VII is called 'Spacetime, Invariance, Covariance'. Here, a paper on Herrmann Weyl (1988b) is brought together with three papers on the subtle distinctions of invariance and covariance, which were written between 1982 and 1994. Part VIII ('Mathematics and Physics') unites papers from two decades concerned with the relationships between mathematics and physics, papers on Kant (1977), Leibniz (1990b), and the scope of mathematics in physics (1986a, 1997a).

VI

In 2003, Erhard Scheibe was made an honorary member of the Gesellschaft für Analytische Philosophie (GAP). By then, he was no longer able to travel and to participate in the ceremony. Indeed, his final book, *Die Philosophie der Physiker* [The Philosophy of the Physicists] (2006, 2007), was wrested from the ravages of an increasingly debilitating

[4] Van Dyck (2000, p. 104).

illness, and Scheibe passed away on January 7, 2010, in Hamburg. The presentation given by this final work of the philosophical convictions of the most important physicists of the 20th century became an enormous success. It is now to be read, it seems, as an appropriate legacy of Erhard Scheibe.

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