THE MUSIC OF THE SPHERES SYNTHESIZED FROM MODERN HARMONIES

Longing for the Harmonies: Themes and Variations from Modern Physics

Frank Wilczek and Betsy Devine
Norton, New York, 1988.
361 pp. $19.95 hc
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Reviewed by Victor F. Weisskopf

Recently a large number of books on physics for the uninitiated have appeared. It is good that physicists have begun to be aware of the importance of informing the public about one of the most successful intellectual creations of our time. It also points to a renewed interest of the public in physical science. *Longing for the Harmonies*, by Frank Wilczek and Betsy Devine, is the best such book I have seen. In many ways it is unique. Its fascinating style transmits the excitement and depth of the subject to the reader. Wilczek, a physicist, had the active help of his wife, Devine, a professional writer who is well versed in literature and history. Wonderful quotations from scientists, poets and philosophers put every subject in its historic place. Not only does this help one's understanding, but it also ties the topics to other human concerns. Right at the beginning the authors quote from a famous poem by Keats: "There was an awesome rainbow once in heaven / We know her woof, her texture / She is given in the dull catalogue of common things." But, reading their book, that catalog is anything but dull. Knowledge adds to beauty.

The title and subtitle allude to a parallel betwen music and physics. In music there exist structure, harmonies, broken symmetry and internal consistency that seem to be related to physics in some intriguing way. The authors are very much aware of this. The spectra of the elements are the "music of the spheres," whose harmonies are recognized by modern science.

The themes for the authors' variations are the structures found in the world around us. They are organized in an unconventional way. We learn at the beginning about the identity of "earth-stuff" and "star-stuff," about how the complexity of nature arises from the large number of atoms in the relevant entities. We are right away introduced to the expanding universe, to the Big Bang and to the lack of complexity at high temperatures during the early instants of the universe. Wilczek and Devine refer to the fight between energy and entropy. They introduce the weak interactions early, before other

Victor F. Weisskopf is a theoretical physicist at MIT who since the 1920s has contributed to quantum electrodynamics, nuclear physics and elementary-particle physics. He is noted also as an outstanding popularizer of science in such books as *Knowledge and Wonder* (MIT P., Cambridge, Mass., 1979).

Albert Einstein (left) is in his mid-30s in this picture from *The Pólya Picture Album: Encounters of a Mathematician* (George Pólya; Gerald L. Alexanderson, ed.; Birkhäuser, Boston, 1987; 160 pp.; $35.00 *hc* ISBN 0-8176-3352-9). Einstein is shown here with Adolf Hurwitz and Hurwitz's daughter, Lisi. In a brief biographical sketch Alexanderson writes that it was Hurwitz who arranged for Pólya's first appointment in 1914 at ETH (Swiss Federal Institute of Technology). Among many contributions by Pólya to probability was a paper in 1921 on 'random walks'—his term. The book includes about 130 mostly candid photographs of many well-known physicists and mathematicians, including Constantin Carathéodory, Elie Cartan, Frank Harary, G. H. Hardy, Felix Klein, Gösta Mittag-Lefler, Emmy Noether, Henri Poincaré, Hermann Weyl and Norbert Wiener.

Of John von Neumann, also pictured in the book, Pólya writes, "He is the only student of mine I was ever intimidated by. He was so quick. There was a seminar for advanced students in Zürich that I was teaching and von Neumann was in the class. I came to a certain theorem, and I said it is not proved and it may be difficult. Von Neumann didn't say anything but after five minutes he raised his hand. When I called on him he went to the blackboard and proceeded to write down the proof. After that I was afraid of von Neumann." —PHA

forces, because these interactions cause transformations among elementary particles, thus breaking the prejudice of permanence.

Of course the most sensitive topic is quantum mechanics. The theme here Wilczek and Devine call "Quantal Reality," emphasizing that there is such a reality. The first part, about particle–wave duality, is as excellent and exciting as most of the other parts of the book. They introduce the term "lave," a combination of "lump" and "wave," for the quantum description of a particle—what Arthur Eddington called a "wavicle." They harshly criticize the Copenhagen interpretation, accusing it of introducing two separate realms of reality: the quantal world and the classical one. I do not think this accusation is valid, but a "correct" interpretation of the Copenhagen view is a problem by itself.

I find it unfortunate that the authors embrace the many-worlds interpretation as a solution to the logical difficulties of quantum mechanics. It does not seem to be a meaningful concept; it also unnecessarily mystifies the uninitiated. Obviously the conclusions from a given "lave" cannot be applied to a single system. Probabilistic predictions make sense only for a large number of identical systems, as we encounter in most applications of quantum mechanics. We get into trouble when we apply the "lave" concept to the total universe. Because there is probably only one such entity as the universe, quantum mechanics loses content. Perhaps the recent ideas about many universes, all starting with inflationary expansions of quantum fluctuations in empty space, will give meaning to a probabilistic interpretation of the quantum state of the universe, but there is no way to check it. Whether one agrees or not, this section of the book is as exciting as the others and makes for intriguing reading. Wilczek and Devine describe the quantum effects of the indistinguishability of elementary particles by postulating an "identity-force," a useful concept for demonstrating why electrons stay apart from one another and photons do the opposite.

Next is an introduction to the field concept, using as an example the electromagnetic field and its quantum description by means of Feynman diagrams. I found it most successfully done, but I have some troubles with the treatment of antimatter. Here the authors use the picture of the positron as an electron moving in the opposite time direction. There is a danger that the uninitiated reader will take this literally. It is not said clearly enough that this description is only a useful formal trick to simplify Feynman diagrams.

The following themes acquaint us with gluons and quarks—and with asymptotic freedom. There is a charming account of how Wilczek was drawn into this problem and solved it. We then learn about the electroweak connection as an example of greater harmony at high energies.

The rest of the book is devoted to the problems of the origin of the universe and how they may be resolved by an early inflationary expansion. The last theme is called "Quest." This section covers most of the recent efforts to solve the great remaining riddles of nature such as dark matter, the cosmological constant, grand unified theories and supersymmetry. Perhaps fortunately, superstrings are omitted.

The book deals mainly with high-energy physics. This is understandable since the harmonies the authors long for are hidden at lower energies. This exposes them to the charge of reductionism—of claiming that if we know the constituents of matter and the forces between them, then we have solved all problems and have reached the "theory of everything." They defend themselves aptly against that accusation with the following metaphor: You cannot explain what music is just by playing each note on the piano and maintaining that the rest is nothing but different combinations. Yet it is of fundamental importance to find the notes that nature combines to compose its structures.

The question remains, for whom is the book written? Certainly physicists and physics students would profit by reading it. They would enjoy the lively style and the unusual way things are presented. Teachers may learn a lot about how to improve their own presentations. What about the uninitiated lay public? Certainly many parts ought to be perfectly understandable. The lay reader will be fascinated by the excitement and the closeness of the problems to general human concerns. But some sections are most probably beyond comprehensibility for most lay readers—in particular, the parts on the latest speculations in particle theory and cosmology. There is a tendency in popular books to cover everything up to the latest topics, which may not survive future scrutiny. But these may prove more confusing than enlightening to the outsider. Unfortunately, this remarkable book is not without this blemish. Despite this and some other drawbacks, it is a pioneering work that shows new and

effective ways of presenting physics to the general public.

The Probabilistic Revolution, Volumes 1 and 2

MIT P., Cambridge, Mass., 1987.
$60.00 hc ISBN 0-262-11125-X

Volume 1: Ideas in History

Edited by Lorenz Krüger, Lorraine J. Daston and Michael Heidelberger
xv + 449 pp.
$32.50 hc ISBN 0-262-11118-7

Volume 2: Ideas in the Sciences

Edited by Lorenz Krüger, Gerd Gigerenzer and Mary S. Morgan
xvii + 459 pp.
$32.50 hc ISBN 0-262-11119-5

Thirty-one American, British, Canadian, Finnish, German and Hungarian scholars, including several well-known historians and philosophers of science, have invented "the probabilistic revolution," a wonderful historical event that took place during the century and a half after 1800. Even though I. Bernard Cohen and Ian Hacking, who specifically address the question "Was There a Probabilistic Revolution 1800–1930?" cannot bring themselves to give an unconditionally affirmative answer, and though Thomas S. Kuhn avoids mentioning it at all in his brief essay on the nature of scientific revolutions, the idea provides an excellent basis for a coherent collection of articles. The three introductory pieces by Kuhn, Cohen and Hacking will appeal to a wide range of readers; the others are intended for specialists.

Some of the authors attempt to define the essential feature of the probabilistic revolution. Perhaps the most appropriate definition (exemplified by the book itself) is a shift in emphasis from statistical uniformity to fluctuations and individual diversity (Theodore M. Porter and Jan von Plato, seemingly contradicted by Hacking). Other proposals, defended with much skill and copious evidence, are the replacement of the subjectivist concept of probability by the frequentist definition (Andreas Kamlah); the introduction of probabilistic statements about the accuracy of measurements (Stephen M. Stigler); the application of probabilistic con-