A Geophysical Entrepreneur

Appropriating the Weather. Vilhelm Bjerknes and the Construction of a Modern Meteorology. ROBERT MARC FRIEDMAN. Cornell University Press, Ithaca, NY, 1989. xxii, 251 pp., illus. $34.95.

Vilhelm Bjerknes (1862–1951), meteorologist and éminence grise of the Bergen school, is familiar, at least by name and reputation, to most atmospheric scientists. This is largely due to the major transformation of meteorological theory and practice, emanating from Bergen, Norway, after World War I, which brought the world, among other things, a new cyclone model, the polar front theory, air mass analysis, and a host of active, aggressive, and creative young meteorologists. Almost unknown today, however, is Bjerknes the failed classical physicist, opportunist, disciplinary entrepreneur, manager, and propagandist.

According to Friedman, Bjerknes originally turned to atmospheric studies to avoid professional decline as a theoretical physicist. As a youth at the 1881 Paris International Electric Exhibition, Bjerknes amazed such international celebrities as Hermann von Helmholtz and Lord Kelvin with demonstrations of his father's work in hydrodynamics. Later, after studying with Heinrich Hertz (himself a student of Helmholtz's), Bjerknes found his earlier career dominated by the desires of his father, who was relying on him to complete and publish his early work. Bjerknes, pursuing the twin grails of perfect filial loyalty and the unification of mechanical physics through hydrodynamics, found himself without a viable research program of his own, increasingly isolated from the mainstream of continental physics, and on the verge of a nervous collapse.

He was rescued from his "arduous, almost thankless efforts in theoretical physics" (p. 46) by his "conversion" at age 36 to a research program in geoscience, which soon brought him the international attention, reputation, and authority he craved. His program included redefining, reclassifying, and restructuring meteorological science. First, he announced a plan for creating an exact physics of the atmosphere, then (as had his mentor Hertz) he devised graphic methods for analyzing atmospheric processes. By involving himself with the growing fields of aeronautics and aerology, Bjerknes gained not only the data he needed but, more importantly, the leadership of a new institute for geophysics in Leipzig in 1913.

Returning to Norway during the war, Bjerknes solicited and obtained government support for practical weather forecasts useful to aviators, farmers, and fishermen. The West Norway Weather Bureau, located in the Bjerknes family residence in Bergen (in style not unlike Bohr's institute for theoretical physics at his home in Copenhagen), became the center of a new school of nonmathematical meteorological analysis. This was an ideal situation for Bjerknes, who was not particularly good at math and was most productive when surrounded by skilled assistants. Believing that their system of air mass analysis could best satisfy the problems facing postwar meteorology, "apostles" and "missionaries" of the Bergen school traveled far and wide in their efforts to "convert" their foreign colleagues (p. 197) and redefine the Norwegian periphery as a new international center—not, ironically, of atmospheric physics, but of new methods for practical forecasting. Thus Bjerknes and his assistants appropriated the weather "as professional property that could be exchanged for authority, resources, and prestige within the world of science and in society" (p. xiii).

Friedman goes out of his way to tell us what the book is not: it is not a biography—we learn little of Bjerknes's early or later life, or how he came to be interested in studying the atmosphere. It is not a comprehensive history of the meteorology of this period—although occasionally Bjerknes himself mentions, usually disparagingly, the work of others. It is not a history of the Bergen school's endeavors—the accomplishments of Jacob Bjerknes, of Bergeron, Rossby, Solberg, and others are presented only as they relate to Vilhelm's career. Nor, according to Friedman, is it a case illustration of any particular model or theory of scientific change—although he does express well-formulated views on this subject, concluding that the "emergence of the Bergen meteorology illustrates new knowledge arising through changes in practice. . . . Hard facts were not waiting in nature to be uncovered. Bergen scientists constituted their new concepts and models by drawing upon analogy, metaphor, existing theory, and ad hoc construction" (p. 243). Finally, the book is not at all polemical, even though Friedman has "perspectives and interpretations that conflict with some received ideas on the history of this particular chapter of meteorology" (p. xiv).

Vilhelm Bjerknes

In essence the book is a carefully crafted narrative analysis of the interconnected history of Bjerknes's career and the construction of a new meteorology. By at least three criteria Friedman's effort rates five stars: his book is solidly based on archival sources; the career of Bjerknes, the rise of the Bergen school, and the development of scientific theory in meteorology are all placed in their contemporary social setting; and the book avoids using today's understanding of the atmospheric sciences to comprehend the history of early-20th-century meteorology.

Beginning with his 1978 dissertation on Bjerknes (a copy of which is available, by the way, in the Francis W. Reichelderfer Papers in the Library of Congress), Friedman the historian has appropriated Bjerknes the meteorologist as professional property. The history of Bergen meteorology, like meteorology itself after World War I, has been greatly enriched by this.

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Broken Symmetries

CP Violation. C. JARLSKOG, Ed. World Scientific, Teaneck, NJ, 1989. x, 723 pp., illus. $84. Advanced Series on Directions in High Energy Physics, vol. 3.

Symmetry has always fascinated scientists, especially physicists. From the ancient theories of circular orbits for the planets to modern superstring theory, we tend to build our theories using ideas and mathematics based on symmetry. However the existence in nature of broken symmetries or near symmetries is often even more interesting. For example, the observation of elliptical, not circular, planetary orbits led to Kepler's laws and was a powerful stimulus in the development of Newtonian mechanics. A more modern example is the observation of the violation of parity (spatial reflection symmetry), one of the first ingredients in weak interaction physics and unified gauge theories.

At present two forms of symmetry breaking intrigue elementary particle physicists. One of these involves the underlying structure of the broken symmetry of the electroweak gauge theory of Weinberg and Salam. Here the underlying symmetry of the theory is removed by interactions of a hypothesized "Higgs boson." There are aesthetic arguments against this Higgs mechanism, although no compelling alternative exists. A prime goal of the proposed superconducting supercollider will be to test this scheme and find the Higgs boson, if it exists. The other form of symmetry breaking now attracting attention involves CP violation. Here C refers to the operations of charge conjugation, that is, the interchange of a particle and its antiparticle. P stands for the parity transformation, the inversion of all spatial coordinates through the origin ($x \rightarrow -x$). Even though both C and P are maximally broken in the weak interactions, their combined operation is very nearly a symmetry. Twenty-five years ago the first evidence for CP violation was found as a 10^{-3} effect in the decays of K mesons. No other CP violation has been found outside of K decays.

Both of these topics are interesting because they may take us beyond the present standard model. (Indeed they may be related, because all known mechanisms of CP violation involve the Higgs sector of the theory either directly or indirectly.) The standard model is a self-consistent structure sufficient to explain current data, but we are looking for a glimpse beyond it. CP violation may be a key to this because, as a rare effect, it has the magnitude appropriate for interactions mediated by particles heavier than those produced at present accelerators.

This volume contains 18 reviews on many of the important topics in the study of CP symmetry. The intent appears to be to provide a snapshot of present work in the field. Similar material is most often available in journals, but the book accomplishes a valuable service in drawing it together.

The book opens with a lucid description of the basic theoretical background of CP violation by Jarlskog. Complementary experimental reviews by K. Kleinknecht and S. Stone thoroughly describe the studies of weak decays of kaons and B mesons. These reviews would be useful for students starting work in the field or even browsers who want to find out what is being studied.

Next come nine papers on possible future signals and alternate models of CP violation. Of these, the one that will probably have the greatest utility and longest lifespan is the survey of B meson physics by I. Bigi, V. Khoze, N. Uraltsev, and A. Sanda. The decays of B mesons display a rich variety of possible signals, and considerable effort is being expended in Europe and the United States to create facilities that can see this form of CP violation. This field will be active for at least 10 to 15 years, and Bigi *et al.* here provide the most thorough and readable account of the issues that I know of. I have seen no review comparable to the excellent summary of electric dipole moments by S. Barr and W. Marciano. On the negative side, I found L.-L. Chau's discussion of signals in B and K decays misleading, since Chau has not updated her previous analysis to include either tightened experimental constraints or further theoretical analysis.

One of the enjoyable aspects of working in the field of CP violation is the variety of related theoretical issues. The last six chapters of the book tour some of these. I greatly enjoyed the chapter "Strong CP problem" by R. Peccei. This title refers to the strong interaction, quantum chromodynamics, which could easily violate CP but apparently doesn't. This seems unnatural in the standard model, and many interpret it as indicating some new physics, such as new particles called axions. Peccei carefully discusses the issues. E. de Rafael's chapter on chiral perturbation theory is a readable, but brief, introduction to this subtle and useful tool.

My greatest concern about the book is that most likely it will become out of date reasonably quickly. With the exception of those by Bigi *et al.* and Peccei, most chapters involve theoretical or experimental methods that are evolving fairly rapidly. Some of the data in the book are already out of date, and even some of the theoretical analyses have progressed noticeably. The book is also incomplete in some regards. For example, two promising new directions that are receiving considerably scrutiny, $K_L \rightarrow \pi^0 e^+ e^-$ and hyperon decay asymmetries, are not discussed. It is, however, a reasonable summary of the present status of the field.

Overall, the volume offers a generally readable entry into this field for a reader who has a basic background in particle physics.

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Celestial Spectra

Multiwavelength Astrophysics. FRANCE A. CÓRDOVA, Ed. Cambridge University Press, New York, 1988. xii, 400 pp., illus. $59.50.

Two or three years ago, I thought it would be instructive to show students spectra of compact celestial sources ranging all the way from 100 MHz in the radio domain to the highest energy gamma rays around 10^{15} eV or 10^{30} Hz. I know of no single compendium of such information, and I had to gather much of it from odd sources.

My first act in reading *Multiwavelength Astrophysics*, therefore, was to leaf through it to see how many such spectra were shown. There are three, perhaps not covering quite the full range of available wavelengths, but at least spanning more than 10 orders of magnitude. They represent Cyg X-3, for which 20 orders of magnitude are covered, 3C273, and NGC 4151. In addition, ζ Puppis, 3C345, and Mrk421 are shown with spectra that cover close to 10 orders of magnitude in frequency. Of course such spectra tend to be coarse, primarily showing the power distribution across the spectrum. Finer features detailing chemical makeup, state of ionization, and pressure or temperature, only show up at higher resolution. Still, it was refreshing to find so many of these broad spectra.

The book is divided into two major parts. The first is by far the most extensive and is arranged according to type of celestial source—the sun, active late-type stars, hot stars, cataclysmic variables, x-ray binaries, classical novae, x- and γ-ray bursts, supernovae and their remnants, interstellar matter in elliptical galaxies, and active galactic nuclei. By any standards, the individual chapters are excellent reviews of their respective fields. Most of them emphasize the fact that the astrophysical conclusions are based on observations at a variety of wavelengths, but others leave that inference to the reader.

Jeffrey Linsky's paper on the active late-type stars is particularly explicit in demonstrating that polarization measurements, or shifts in spectral line frequencies with time, or any of several other types of correlative observations lie at the heart of star-spot analyses: multiwavelength astrophysics is not just a one-dimensional game involving wavelength.

Part 2 of the book deals with the methodology of multiwavelength observations. In three chapters, it identifies available databases and the centers where analyses can be carried out; lists capabilities of current instrumentation, giving a description of its uses in several wide-ranging campaigns on such sources as Halley's comet and Cyg X-3;