

Inventing Atmospheric Science

Bjerknes, Rossby, Wexler, and the Foundations of Modern Meteorology

James Rodger Fleming

MIT Press, 2016. \$31.00 (296 pp.).

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James Rodger Fleming of Colby College is well known for his numerous books on the history of meteorology. One of his first was *Meteorology in America, 1800–1870* (Johns Hopkins University Press, 1990), which documented the rise of weather science; during the 19th century, the field grew from individuals making backyard observations to weather-forecasting networks spanning continents.

Fleming's latest book, *Inventing Atmospheric Science: Bjerknes, Rossby, Wexler, and the Foundations of Modern Meteorology*, is in some ways a continuation of that early work. By examining the lives and work of three prominent meteorologists—Norwegian Vilhelm Bjerknes, Swedish-born American Carl-Gustaf Rossby, and American Harry Wexler—Fleming shows how, over the first half of the 20th century, the enterprise became a world-spanning, full-fledged science. He also shows how the three scientists' work contributed to the founding of modern forecasting and the National Center for Atmospheric Research in the US.

Bjerknes conducted his work from the late-19th to mid-20th centuries and bridged the transformation of weather forecasting from a subjective, intuitive art to an objective science. One of his first accomplishments was to generalize Maxwell's electromagnetic field equations to fluid-dynamic formulas, a strategy that laid the groundwork for numerical weather prediction. On the practical side, Bjerknes established a weather forecast center in Bergen, Norway, that became a training center in the new methods of polar-front and air-mass analyses. Meteorologists who studied at the Bergen "school" included Francis Reichelderfer, Tor Bergeron, and Rossby.

During the early 1930s, Rossby tried to bring the insights of the Bergen school to the US Weather Bureau (now the National Weather Service). Frustrated by

the bureau's rejection of those new ideas, he carried out dishpan experiments in the bureau's basement. Those led him to insights about upper-atmospheric circulation and the jet stream, and to the discovery of what are now known as Rossby waves—atmospheric and oceanic waves that result largely from planetary motion. Between his bouts of employment at the bureau, Rossby founded the meteorology departments at MIT and the University of Chicago. He also established a program to train weather forecasters for the US armed services during World War II. Students of those programs included George Platzman, Horace Byers, and Wexler.

By his teacher Rossby's evaluation, Wexler had his "fingers in too many pies." He oversaw the birth of numerical weather prediction, studied climatology, evaluated intentional and inadvertent weather modification, and promoted the use of artificial satellites to monitor the weather. His efforts, detailed in Fleming's new book, helped define the now burgeoning field of atmospheric science.

In addition to the three main subjects, Fleming offers minibiographies of some of their colleagues, including Anne Louise Beck, Jule Charney, and Jerome Namias, who also made contributions in modernizing weather science. Fleming presents segments on the major technological innovations that drove scientific advance as much as scientists did. Rawinsondes (which profile wind velocity and other atmospheric parameters as a function of height), radars, computers, and satellites brought revelations about the structure and dynamics of the atmosphere; the new data required a rethinking of theory, and that in turn led to better forecasting.

In his introduction, Fleming promises his readers that the book will be generally accessible to nonexperts. That isn't entirely true. Much of his discussion of the developments of the science will be opaque to anyone not familiar with the basics of meteorology. In the first chapter, he references many 19th-century developments in physics and meteorology as if readers were already acquainted with them. It might be best if readers first peruse his *Meteorology in America* for a proper grounding in the names and evolution of the science prior to the period



discussed in this book. Fleming takes the time to define "in the catbird seat" but does not do so for terms such as convection, convergence, and cyclogenesis. Nongeophysicists might want to keep a meteorological glossary handy. We scientists often forget that our jargon is obscure to the general public.

Readers might be disappointed to find that even for the book's three principals, Fleming does not offer "life in full" biographies. For Bjerknes and Rossby, a lot of text is given over to reciting conferences attended, committees formed, and institutions founded; for Wexler, more details are given about his private life, perhaps because his family supplied Fleming with a treasure trove of personal letters and papers. At the end, we are given a warm, intimate look at Wexler, while poor Bjerknes comes off as a bit of a cold lutefish.

Inventing Atmospheric Science should certainly be read by those interested in scientific and, in particular, meteorological history and policy. It covers a critical period in the development of the atmospheric sciences and how modern weathercasting came to be.

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The Jazz of Physics

The Secret Link Between Music and the Structure of the Universe

Stephon Alexander

Basic Books, 2016. \$27.50 (254 pp.).

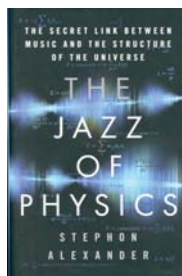
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In *The Jazz of Physics: The Secret Link Between Music and the Structure of the Universe*, Brown University physics professor and saxophonist Stephon Alexander writes that he set himself "the challenge to find an isomorphism between jazz and cosmology," his two great intellectual and spiritual pursuits.

His formal resolution to that quest appears in "A cyclic universe approach to fine tuning," a paper that he, Sam Cormack, and Marcelo Gleiser published in a June 2016 issue of *Physics Letters B*. As Alexander explains in his book, the idea

behind the paper was to identify a jazz musician's improvisation through a cyclic chord pattern with the universe "improvising" new fundamental constants (due to the dynamics of a ghost-like scalar field) through each cycle of a closed bouncing universe. Much of *The Jazz of Physics* is dedicated to providing enough physics to explain the fine-tuning problem—Why do the fundamental constants take on values that allow the universe and us to exist?—to describing other physics concepts that are central to his paper, and to making connections from them to jazz and music more broadly.

Over the course of the book, Alexander explores physics concepts by focusing on general relativity and string theory, with its associated M-theory and D-branes. He also takes the reader through his own personal detours into neuroscience and biophysics, including work relating the Ising model of quantum mechanical spins to connections between neurons. We return to the bound-



ary between music and physics, where Alexander discusses acoustic analogs to black holes, in which a shock front in an acoustic medium can keep information from propagating back against the shock just as an event horizon keeps information from leaving a black hole.

He devotes an extended chapter to the inflationary universe and introduces the cosmic background radiation, its power spectrum, and the horizon problem. Readers learn that the power spectrum is driven by acoustic waves in the early universe—thus, the universe is an instrument that plays itself.

Musically, we touch on the circle of fifths and the "sheets of sound" that exploded onto the scene with saxophonist John Coltrane's 1960 album *Giant Steps*. We meet the pop and avant-garde musician and producer Brian Eno at a quantum gravity reception. Alexander later called him a "sound cosmologist." From a visit to Eno, Alexander draws a lesson about synthesizing arbitrary sounds from pure sine waves. A discussion of avant-

garde composer John Cage's theory that all "sounds are, of their nature, harmonious" brings us to the discovery of the cosmic microwave background, originally seen as "noise" in Arno Penzias and Robert Wilson's detector. The transition demonstrates how few bars Alexander needs to shift between physics and music.

Such a diversity of topics in a book just over 250 pages runs the risk of being facile, and in the chapter called "A Journey into Mark Turner's Quantum Brain," Alexander does cross a line. In that chapter, we learn about both tenor saxophonist Turner's musical style and the uncertainty principle. Turner, who studied the music of Coltrane and pianist Lennie Tristano, observes that "whenever I am most certain of the next note to play, the more possibilities open up for the notes that follow." Alexander uses that peg to hang a description of the uncertainty principle, in which knowledge of the position of a particle opens up more possibilities for its momentum. He then discusses the principle in detail, having already discussed Fourier transforms and

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waves. However, the trope of applying the quantum mechanical notion that measuring something destroys its coherence to a non-quantum-mechanical process like Turner's unique and powerful improvisations hits an off note, at least to me.

At the heart of the book lies "Coltrane's Mandala," which combines the symmetries of the 12 notes of the western chromatic scale (A, A#, B, C . . . G, and G#) with the 5 notes of the pentatonic scale (A, C, D, E, and G) used in musical styles throughout the world, including jazz. *The Jazz of Physics* opens with an enigmatic visit by Alexander to the since deceased Yusef Lateef—a jazz multi-instrumentalist who was then a University of Massachusetts professor—for a discussion of the Mandala. It closes with an argument that Coltrane created the Mandala by synthesizing his understanding of relativity and applying it to his music.

The most interesting portions of the book are autobiographical. Alexander grew up in a Trinidadian family living in the Bronx. Later, he would discover the beauty of learning and the thrill of performing music and physics. And in time, he would rub shoulders with distinguished musicians and physicists. His stories are rich and personal; in them we see originality in physics and music and the growth of a mind finding its own path. Not only does he show the title and abstract of "A cyclic universe approach to fine tuning," but he also offers an image of the cover art of his 2014 album with Erin Rioux, *Here Comes Now*. Alexander communicates the joys and fears of life on the knife-edge of creativity.

But did Alexander achieve his goal of uncovering an isomorphism between physics and jazz akin to that between a resonant electrical circuit and a mechanical oscillator? Perhaps he has, though his short readable book does not present enough detail for the evaluation of such a claim. However, he has accomplished at least as much by presenting the metaphors driving creative inspiration in the creation of both new physical insights and new beautiful sounds.

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