PHYSICS

Giant Ring on the Prairie

Robert W. Seidel

Fermilab
Physics, the Frontier, and Megascience

by Lillian Hoddeson, Adrienne W. Kolb, and Catherine Westfall

University of Chicago Press, Chicago, 2008.
513 pp. $45, £31.
ISBN 9780226346236.

Few readers of *Science* will be unaware of the Fermi National Laboratory and its programs. Like Ernest Lawrence's Radiation Laboratory, Brookhaven National Laboratory, and CERN, it is a pioneering institution in high-energy physics. Until the Large Hadron Collider at CERN goes into operation, it will continue to lead the field in terms of the energy of its accelerator, the Tevatron. Unlike those institutions, however, Fermilab has, until now, lacked a history worthy of its accomplishments and historical significance.

Therefore, it is delightful to have in hand and to read the work of historians Lillian Hoddeson, Adrienne Kolb, and Catherine Westfall. *Fermilab* weaves their accounts into a coherent narrative in limpid prose that should be accessible to anyone with an interest in the history of late-20th-century science. Although the laboratory engaged in a number of highly technical projects, the authors lead the reader through those faithfully without sacrificing the essence of the laboratory's ambitions and accomplishments. Their artful depiction of the origins and growth of the laboratory under its first two directors, Robert R. Wilson and Leon M. Lederman, makes clear the challenges Fermilab faced in achieving leadership in high-energy physics despite difficult political and scientific fortunes.


The site in 1977. Main ring.

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The origins of Fermilab, explored extensively by Catherine Westfall in her Ph.D. dissertation, form the focus of the book's first chapters. One of the casualties of Cold War competition in high-energy physics was the Midwest Universities Research Association's plan for an advanced accelerator, which fell victim to the Joint Committee on Atomic Energy's desire to exceed the energy of a 10-GeV Soviet accelerator by instead constructing a 12-GeV proton synchrotron at Argonne National Laboratory. After the high-energy physics community, acting through the Atomic Energy Commission (AEC), supported the Lawrence Radiation Laboratory's design of a 200-GeV machine and Stanford's 2-mile electron linear accelerator (SLAC) in the early 1960s and Brookhaven won support to study a follow-on 1000-GeV machine, the flyover states sought redress from Washington for their grievances. The democratic inclinations of the Great Society and the complaints of physicists excluded from beam time on the Berkeley and Brookhaven accelerators forced the AEC into a overt site selection competition under the aegis of the National Academy of Sciences, which resulted in the selection of a Weston, Illinois, site. Berkeley's designers were insulted by the choice and injured by the attacks on their design by Wilson, who excoriated the extravagance and irrelevance of the accelerator and claimed he could build it more economically and expeditiously. Once inseminated with this idea, the AEC abandoned its efforts to move California physicists to the prairies of Illinois and embraced Wilson as the pioneer of the venture.

As promised, but not without difficulty, Wilson assembled the accelerator on time and under budget—although, as the authors explain, his "cut and try" approach led to some fairly spectacular mistakes in the construction. Wilson's frugality, appropriate to the Lawrence's Depression-era laboratory in Berkeley where he had begun his career, frustrated the potential users of what had been billed a "truly national laboratory," especially when they were required to supply their own experimental equipment to the leaky temporary buildings that Wilson allowed to take up positions around the ring. His own contributions to the design of the laboratory were artistic and ecological, from the high-rise headquarters to the buffalo that occupied the restored prairie in the main ring. This recreation of the frontier, the authors emphasize, symbolized the ideology and rhetoric Wilson employed in his vision for the laboratory. Wilson achieved twice the design energy despite the political exigencies of the 1970s—Vietnam, energy crises, the demise of the AEC, and the growth of the Department of Energy (DOE) bureaucracy—although his distaste for computers and other frills and extras that preoccupied high-energy physics laboratories elsewhere certainly played a role in the disappointment some felt with the results.

When the DOE failed to support his initiatives to retrieve the situation by building another accelerating structure with superconducting magnets to again double the energy of his machine, he resigned—and the Laboratory's contract manager surprised him by accepting his resignation. He was succeeded by Lederman, an able scientific citizen whose string of experiments set the pattern for user homesteading of experimental areas around the ring. He led Fermilab out of the wilderness into the promised land of bigger computers, bigger detectors, colliding-beam accelerators, and sounder management. The new ring of superconducting magnets (built below the original main ring) gave way to a 1000-GeV machine, the Tevatron, which required the kinds of massive detectors and data-analysis networks already under development at CERN, SLAC, and other high-energy laboratories.

Lederman, however, overreached in seeking first to assemble an international consortium to build a very big accelerator, which became the Superconducting Super Collider (SSC) once the Reagan administration deemed it an appropriate effort for the community they hoped would produce the Strategic Defense Initiative. Lederman won the Nobel Prize and departed for the University of Chicago before the SSC was sited in Texas. He left John Peoples to redeem Fermilab and bury the SSC by reinvigorating research in Illinois and shutting down the Waxahachie ring after Congress terminated the project in 1993.

By careful selection of their detailed case studies (e.g., the main ring and Lederman's string), the authors provide sufficient detail to understand both the value and the achievements these represent. They illuminate the laboratory and political contexts that contributed to failures and successes on the high-energy frontier. Fermilab's story is well told and attractively framed in the book, a fitting capstone for the edifice of historical scholarship

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that the authors have erected over 30 years. Megascience requires "megahistory," and Hoddeson knows how to pioneer in that field.

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ASTRONOMY

Through a Glass of Darkness

Pedro Ferreira

"Astronomers don't know math," a colleague of mine once said. He is a bit of a troublemaker, and what he said was bizarre, unfair, and quite clearly incorrect. But I understood what he was getting at: when astronomers unleashed the power of mathematics—and by that I mean the wonderful, exciting, cutting-edge mathematics of geometry and statistics that has emerged over the past century—there would be many wonderful things to discover out in the cosmos. My belligerent colleague felt that astronomers simply didn't do enough of it.

Einstein's Telescope
The Hunt for Dark Matter and Dark Energy in the Universe

by Evalyn Gates

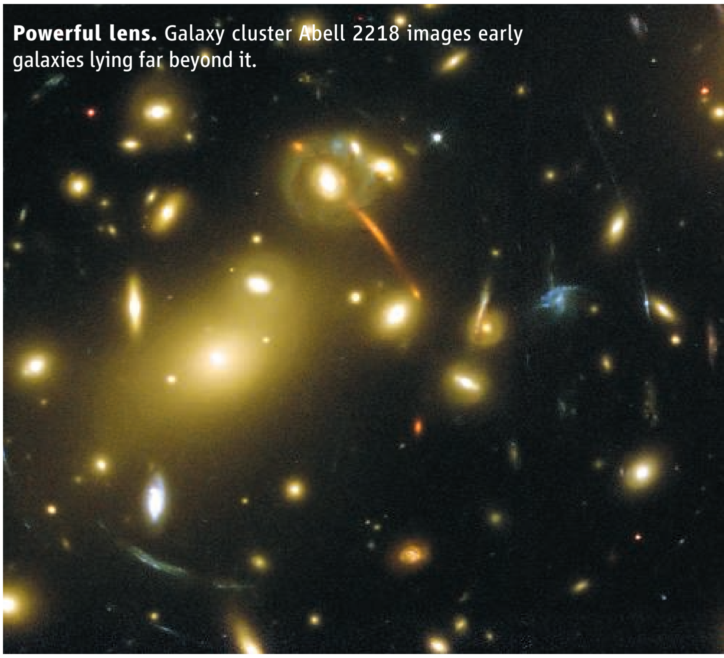
Norton, New York, 2009.
328 pp. $25.95, C$28.50.
ISBN 9780393062380.

Evalyn Gates's *Einstein's Telescope* is a testament to what can be done when beautiful mathematics is applied to astronomy. Einstein's general theory of relativity gave us a revolutionary new way of understanding the force of gravity, which effectively governs the behavior of the universe on large scales. Einstein argued that space-time took on a life of its own and in doing so would affect the way things moved. In particular, he showed that the paths of light rays would be deformed by the presence of massive objects like planets, stars, galaxies, and clusters of galaxies. And by looking at the how light rays are deformed, we might be able to learn about not only the light sources but also the objects that have warped the space through which the rays propagate, i.e., the lenses. In my mind, this is one of the most wonderful applications of elegant mathematics and has led to truly groundbreaking observations. Astronomers do know math.

The bulk of *Einstein's Telescope* focuses on the history and important advances in the field of gravitational lensing, and Gates tells the story well. A particle astrophysicist at the University of Chicago's Kavli Institute for Cosmological Physics, she has worked on a number of aspects of dark matter and its astrophysical consequences. She has also been an active promoter of outreach, as a former vice president for science and education at Adler Planetarium in Chicago. Gates is therefore well equipped to come up with clear, well-thought-out explanations of the various areas in which lensing is used. So, for example, she expertly walks us through the minutiae of detecting what are known as massive compact halo objects (MACHOs—a contrived acronym, I know) and the quest for extrasolar planets. She describes the progress in weighing clusters of galaxies through their effect on the light emitted from the tapestry of distant background galaxies, an approach that has provided a genuinely new view on how mass is distributed in the universe. One of my favorite parts is her description of gravitational lensing by stellar black holes. Although some pundits predicted that the required alignment of Earth-hole-star would be too rare to be observable, two separate teams were able to detect such an event in the bulge of our galaxy. That lens remains, according to Gates, "the only lone stellar-mass black hole ever discovered." All in all, this is a story of teasing out improbable, almost indiscernible signals to great effect.

The author chose a considered, meticulous style for most of the book. She digs into the details of how things work and doesn't dwell on personal anecdotes about the various protagonists. This approach makes for drier reading than many other books in the field, although Gates does sprinkle the text with "compelling," "unprecedented," and "beautiful," adjectives that are de rigeur in cosmology. And I fully support her approach because she makes the science (and the math that underpins it) tell the story, and the story is indeed compelling. In her preface, Gates suggests that readers look at the set of color illustrations at the book's center before they start reading and then look at those figures again after having finished. This is a helpful recommendation because, read carefully, her explanations of gravitational lensing and dark matter should really enhance the experience and appreciation of the color images.

Unfortunately, toward its end the book loses focus and depth. Gates's explanations of dark matter and dark energy echo what has been written in countless other popular science books and articles. She has, sadly, neglected the effects that gravitational lensing might have on the relic radiation left over from the Big Bang, a truly new frontier in the field. Her claim that "we live in a flat … Universe" would have been acceptable four or five years ago, but it isn't in 2009, when we know that more detailed studies of dark energy have severely hampered our ability to make precise quantitative statements about the geometry of the universe. And the brief section on modified gravity is in places incorrect. Gates claims that, without dark matter, the gravitational field should trace the light, but there are a number of counterexamples where this has been shown not to be true. Her statement plays a crucial role in her interpretation of recent results, and this is one of the situations in which she should have looked at the math in more detail and not only at the pictures.



Powerful lens. Galaxy cluster Abell 2218 images early galaxies lying far beyond it.

CREDIT: NASA, ESA, RICHARD ELLIS/CALTECH AND JEAN-PAUL KNEIB/OBSERVATOIRE MIDI-PYRENEES, FRANCE

Overall, *Einstein's Telescope* is worth reading for its level of detail and the way it brings together the disparate applications of gravitational lensing. Gates uses one of Einstein's great ideas to weave together mathematics, astrophysics, and cosmology into a coherent and, dare I say it, compelling narrative that maps out the frontiers of contemporary research.

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