

but was characterized by the very organization of science and its neat intellectual and disciplinary separation between physics and astronomy. Over the years, Einstein searched essentially in vain for support from German astronomers in checking the astronomical consequences of his theory. They stubbornly refused to cooperate, with the exception of one young assistant at the Royal Observatory in Potsdam, who was himself an outsider—Erwin Freundlich.

Although Freundlich never delivered any immediate observational results supporting general relativity, Hentschel's account admits the conclusion that his contribution to the eventual success of this theory was nevertheless quite significant.

First of all, Freundlich probed an impressive number of strategies for providing empirical evidence for general relativity. Although many of these strategies turned out to be blind alleys, his exploration of them cleared the field and identified the open questions. Unfortunately, Hentschel focuses on only a single example—the statistical investigation of gravitational redshift observations—rather than treating Freundlich's important contribution in a more systematic way.

Secondly, Freundlich's efforts to obtain data from observatories throughout the world drew the attention of numerous astronomers to Einstein's theory. These efforts thus helped to establish, on an international scale, a research program for checking the astronomical consequences of general relativity, a program that contributed much to overcoming the frictions at the disciplinary boundaries between physics and astronomy. In Hentschel's account, it was Freundlich, more than any other person, who had to carry the burden of this struggle. In comparison, Einstein appears as a mighty representative of the Berlin physics establishment on whose whims and woes Freundlich's fortune supposedly depended. Here, Hentschel's picture needs some correction. Recent research by Giuseppe Castagnetti and others, cited but not used by Hentschel, has shown that Einstein's search for a general theory of relativity did not correspond to the expectations of his Berlin colleagues and was considered by them with reserve and sometimes suspicion.

Against this background, a further contribution of Freundlich's to the history of general relativity becomes visible, one that is undervalued in Hentschel's book: Freundlich was one of the few, today mostly unknown, friends and colleagues who served as Einstein's collaborators and discussion partners

in a period of intellectual isolation. An examination of Einstein's notebooks and correspondence shows that the benefit that he drew (or could have drawn) from Freundlich's intellectual partnership was indeed not small, reaching from the first calculation of the gravitational lensing effect during a visit with Freundlich to the discovery by Freundlich of a crucial flaw in a preliminary version of Einstein's theory of general relativity.

The construction of the Einstein Tower in 1921 marks what one may call a preliminary happy end to the intricate story of the emergence of general relativity. As Hentschel points out, for a short historical moment the tower represented the combined success of a new physics and a new architecture as well as of the men behind it: Mendelsohn, Freundlich and Einstein. But the moment was short; with the rise to power of the Nazis, this unique constellation was shattered: The three men were forced to emigrate, while the tower itself lost its name and temporarily became the Institute for Solar Physics—until it regained its original name after the war.

Hentschel's analysis shows that the evanescent character of the constellation represented by the Einstein Tower was a consequence not only of the impact of external forces; the constellation's transience also had intrinsic roots: In particular, the scientific instruments with which Freundlich equipped the Einstein Tower were still decades away from technology that was adequate for the intended testing of general relativity. This, of course, could not have been known to the participants in 1921. That they then hardly had the chance of recognizing the fragility of their joint success is in fact one of the lessons to be learned from this important book. The history of the Einstein Tower suggests that the stability of scientific success may be just as unpredictable as was that of the Tower of Babel.

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Rock Magnetism: Fundamentals and Frontiers

David Dunlop and Özden Özdemir
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A happy accident of nature has provided geophysicists with a remarkable

record of the changing magnetic field of our planet and glimpses of past magnetic fields of the Moon and the early Solar System. This has come about because there are magnetic particles in terrestrial rocks, lunar rocks and meteorites of just the right grain size to be excellent magnetic recorders. Such particles have faithfully preserved their stable remanent magnetism over the eons. The study of the acquisition and preservation of this paleomagnetic record has become known as rock magnetism.

To understand rock magnetism, one must combine fundamental magnetic theory with specialized knowledge of the natural materials and the magnetizations they carry. The need for a separate theoretical basis for rock magnetism arises because the earlier generations of physicists who developed magnetic theory were not much interested in the topics with which rock magnetism is primarily concerned. For example, those who study rock magnetism are interested primarily in understanding remanent magnetization and only secondarily in other magnetic phenomena, such as susceptibility and coercive force; the emphasis is reversed in mainstream magnetic studies.

In *Rock Magnetism: Fundamentals and Frontiers*, David Dunlop and Özden Özdemir have successfully combined rigorous theoretical treatment of the fundamentals of rock magnetism with a necessarily more descriptive discussion of frontier areas in which all is not yet clear. In rock magnetism, one seeks to understand messy natural materials and the processes through which nature has put them. To succeed, one must have an ability to develop simple physical models and also the patience to deal with geological complexity. This combination has proved hard to come by, but is notably demonstrated by the authors in this book. Thus, there are detailed descriptions of the magnetic minerals and the chemical changes they undergo, the domain states in which they are observed and the types of remanence they carry. There is equally thorough development of the micromagnetics and models of remanence. The book is a natural successor to the classic text *Rock Magnetism* by Takeshi Nagata (Maruzen, second edition, 1961) and comprehensively reflects the present state of rock magnetism.

One problem with such an encyclopedic approach is that as a subject grows, the amount of material to be covered becomes a little daunting, and organizing it into a palatable whole becomes tricky. The authors give a brief historical introduction and discussion of basic magnetic theory and then

deal with the magnetic properties of naturally occurring magnetic materials. This is followed by treatment of magnetic fields and energies, domain observations and theories. A series of chapters then covers individual magnetizations, such as thermoremanent, viscous and crystallization magnetization. Finally, the book covers the magnetism of various types of rocks—igneous, sedimentary metamorphic and extraterrestrial. Although the chapter on pseudosingle-domain magnetization, which is concerned with domain state, interrupts the discussion of individual magnetizations, overall the approach works well. I would have enjoyed a little more historical introduction to each topic, to show how the concerns of rock magnetists have changed over the years. However, these are trivial complaints. The key point is that the treatment in the book provides an invaluable source for workers in rock magnetism.

The book has particularly strong sections on domain observations and micromagnetic calculations, which are current and indeed long-standing concerns of rock magnetism. Numerous illustrations accompany the discussion of the various observation techniques, both new and old. The thorough discussion of the basis of the micromagnetic techniques is a particularly valuable contribution. The juxtaposition of domain observations and domain state calculations draws attention to an ongoing challenge: Why do the micromagnetic and elementary energy minimization calculations give a critical single-domain size that is so much smaller than what we observe? Some may say that the key domain observations are unreliable. However, I wonder if we are still neglecting too much in the micromagnetic calculations—nucleation energy, for example.

Perhaps the most difficult task for rock magnetists is to provide paleomagnetists with more help in interpreting the details of that record. Attempts to do this are covered in the book, and successes are noted, but more discriminatory tests for different types of magnetization that would distinguish between primary magnetization (acquired at the time of rock formation) and later, secondary magnetizations would be an enormous contribution. Meanwhile, the scope of rock magnetism continues to broaden, with applications in environmental science, paleoclimatology, archaeology and biomagnetism.

To summarize: This is an excellent, comprehensive text written by prominent researchers in rock magnetism. It will surely be an invaluable source for all workers in the field for a long

time. The book is not only well written, but well produced, with fine diagrams and layout. It is, however, very unfortunate that at \$125.00, it may prove too expensive for many who would benefit from having a personal copy.

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Visions: How Science Will Revolutionize the 21st Century

▶ Michio Kaku
*Anchor Books (Doubleday), New York, 1997. 403 pp. \$24.95 hc
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As we rush toward the turn of the millennium, publishers are pouring out books and articles that crack open various vistas into the future. *Visions*, by Michio Kaku, is such a book. Kaku, a physicist who works on superstrings, states that he writes from a scientific, as opposed to social, perspective. His book is nontechnical and intended for the general public, an audience he has addressed in previous popular books and in weekly science programs on the radio.

Visions is organized into three major sections that describe developments expected from information technology, biomolecular research and fields that could be called "other" (materials science, energy research, aerospace and the like.). He lumps these into great scientific metathemes, which he terms "matter, life and the mind." Breakthroughs in these areas are likewise driven by three 20th-century paradigm shifts that he refers to often in the book, namely, the "quantum revolution," the "DNA revolution" and the "computer revolution." In his introduction, Kaku states that the 20th century has uncovered most, if not all, of the fundamental principles in science (perhaps a bit presumptuous, but again, this is the viewpoint of a string theorist), and we are moving from an age of "discovery" into an age of "mastery," where we are learning to forge these principles into technology.

Kaku's timetable for the future is also broken into a triad. The first interval runs through the year 2020. He assumes that Moore's Law, the exponential growth in microelectronics density, continues to hold throughout, enabling computation, sensing and networking to explode off today's privileged platforms (personal computers and telecommunications, for example) and to permeate our environment in the form of smart spaces, intelligent objects and wearable computers, thus

bringing a cyberpunk vision of the virtual world and networked reality into daily life. The human genome and those of most other species will be sequenced, some notion of functional genetic mapping attained, and the causes of disease understood, leading to many new cures and treatments. His next interval (2020–50) hints at a life where machines will understand natural language and begin to form actual intelligence, while computation itself will turn to other, less obstructed avenues, such as quantum and DNA computing. Functional gene mapping will be well advanced, and personal DNA sequencing will be standard fare, enabling some degree of genetic tampering in offspring, adjustments to the master longevity genes and growth of spare organs for transplant. During the years 2050–2100, Kaku puts it all on the table, giving us true machine intelligence, the ability to tailor our offspring, the "cyborg" fusion of electronic and organic brains (yes, he posits that people born in this era may well be immortal) and vast new sources of energy (fusion, solar and so on) that are needed to power this world and give us space colonies and the first unmanned stellar probes. Although Kaku's voice was very prominent in opposition to the recent launch of the Cassini Saturn probe, with its plutonium generators (which is not broached in this book), he appears to be a supporter of space exploration.

Of course, the first applications of groundbreaking technology have a significantly less-than-perfect track record in modern human history. One can glean dozens of ways to end the world from the technology in each of Kaku's chapters. Although he appears to be an optimist, Kaku doesn't ignore such threats, closing each chapter with a "Second Thoughts" section that illuminates a bit of the dark side. He finishes the book by looking across cosmological timescales, tracing the evolution of humankind from its current fragile "Type 0" civilization (adapting the words of Russian astronomer Nikolai Kardashev) to the ultimate "Type III" beings, who will spread throughout the galaxy and perhaps even escape the big crunch or entropy death at the end of the universe by tunneling through spacetime wormholes to reach other universes that are in better shape.

What saves Kaku's book from the more common genre of personal speculation is the amount of legwork that he did, interviewing over 150 researchers in many different disciplines, all cited in the text and appendix. This gives the book a sense of realism. On the downside, there is significant sloppiness in his interpretations. For in-