books

Charting the cosmos at your desktop

The Making of History's Greatest Star Map

Michael Perryman

Springer, New York, 2010. $29.95 (282 pp.). ISBN 978-3-642-11601-8

A Grand and Bold Thing

An Extraordinary New Map of the Universe Ushering in a New Era of Discovery

Ann Finkbeiner

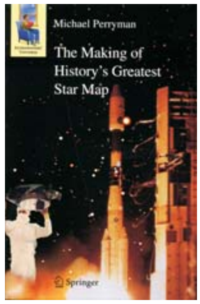
Free Press, New York, 2010. $27.00 (223 pp.). ISBN 978-1-4165-5216-1

Reviewed by Jay M. Pasachoff

Observational astronomy was once a science in which lone observers spent cold nights on remote mountaintops obtaining one spectrum at a time. The makings of two recent celestial maps exemplify a field in which scientists at their desks can access and process huge quantities of archived information on the internet and publish their results as teams of dozens. The new maps are even available to citizen-scientists, at least one of whom discovered an object not previously noticed by the professionals.

In the 1990s the European Space Agency's *High Precision Parallax Collecting Satellite*, or *Hipparcos*, was used to produce a three-dimensional map containing millions of stars. That effort, and a rich history of star mapping, is expertly recounted by *Hipparcos* scientific director Michael Perryman in *The Making of History's Greatest Star Map*.

The *Hipparcos* catalog provides positions, motions, and distances of 120 000 stars, available in five printed and digital volumes, to positional accuracies better than 2/1000 second of arc, roughly 100 times better than can be obtained from our best terrestrial observatories. The project's relatively less accurate Tycho catalog of more than two million additional stars provides standards that are widely used across the astronomical community.



Hipparcos's path to success, though, veered uncomfortably close to total disaster, when its apogee motor failed and the satellite was placed in the wrong orbit soon after its 1989 launch. Resourceful scientists and engineers saved the satellite and eventually figured out a way to process the data so that it made a unified, accurate system of star information across the whole sky.

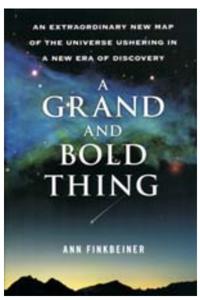
Perryman tells the story well. The book's scientific and historical content is substantial and wide ranging. To its credit, the publisher has included about a hundred, mostly small, photographs. A page is devoted to an image of one page of the printed *Hipparcos* catalog, the one containing data about Sirius, the brightest star in our visible sky.

The distance measurements obtained by *Hipparcos* add solidity to the lowest rung of the cosmic distance ladder, on which all measurements of more distant objects rely. In obtaining their map of the galaxies, the scientists of the Sloan Digital Sky Survey (SDSS) extended a major outer rung of the ladder with the help of spectra and the Hubble-law relation between redshift and distance.

A Grand and Bold Thing: An Extraordinary New Map of the Universe Ushering in a New Era of Discovery is science writer Ann Finkbeiner's fly-on-the-wall account of the SDSS, which has mapped millions of galaxies. Finkbeiner leads us through the project's tortuous beginnings two decades ago to the crowning scientific results that finally came flooding in: The project's sixth data release, in 2007, contained 287 million objects and 1 271 680 spectra. They are all available to us now on the internet at Google Sky, WikiSky, and Microsoft's World-Wide Telescope.

I was at the Institute for Advanced Study in Princeton, New Jersey, when scientists there were teaming up with colleagues at Princeton University and the University of Chicago for the SDSS. The project also involved Fermilab scientists, experts at handling large datasets. Finkbeiner shows how those scientists, novices at astropolitics, brought in the Alfred P. Sloan Foundation for major funding, and how, after years of delays and impediments in somewhat of a free-for-all among talented people, they obtained glorious victory.

A Grand and Bold Thing is an encomium to the scientific leader and inspiration whose hopes and standards were eventually met—James Gunn from Princeton and Caltech. The large and varied cast of characters includes astronomers of all ages, with postdocs, graduate students, and even undergraduates playing major roles as ability to write computer code came to the fore. We learn about dust in and beyond our galaxy getting in the way of the SDSS's 2.5-meter telescope on Apache Point in New Mexico, about the eventual calibration to 1% accuracy of objects across the entire portion of sky accessible to that telescope, and about disruptive moths settling on the telescope's bearings—eventually the SDSS scientists devised a system to clean them off by regular puffs of air.



The SDSS telescope captures images and spectral information using CCD detectors, which have revolutionized astronomy. The telescope can collect more than 5000 spectra per night because of hundreds of fiber-optic strands connected to holes drilled in large metal plates. Finkbeiner brings the story to life with anecdotes about how the collection time per plate was reduced from three hours to five minutes and how the accuracy of labeling individual

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stars' spectra jumped from 70% to better than 99%. Those improvements came once the collection plate's fiber-optic connections were randomly brought together at the camera, through hardware and software improvements, and through relocating a video camera after visiting astronomers noticed that it was not optimally placed.

The last quarter of *A Grand and Bold Thing* describes how Sloan-based results now permeate our understanding of the universe's structure. Those results came not only from SDSS scientists, or "Sloanies," but from other astronomers and even from "The Galaxy Zoo" project involving citizen-scientists around the globe. Accidental additional benefits include an improved understanding of our galaxy's stars, which got in the way of the cosmological observations, and of the asteroids in our solar system—the SDSS discovered tens of thousands of them. Before the SDSS, who knew that the asteroid belt has an inner and an outer family, each with different compositions?

Finkbeiner quotes 18th-century artist Joseph Wright of Derby, known especially for his science-themed oil paintings, who admitted, "I own I can never look upon the stars without wondering why the whole world does not become astronomers." In the 20th century, my generation of astronomers was inspired by our nights at the Palomar or Mauna Kea observatories. Let us hope that the new generation stays inspired by its desktop chases of astronomical reality.

The Physics of Proteins

An Introduction to Biological Physics and Molecular Biophysics

Hans Frauenfelder (edited by Shirley S. Chan and Winnie S. Chan)
Springer, New York, 2010. $159.00 (448 pp.). ISBN 978-1-4419-1043-1

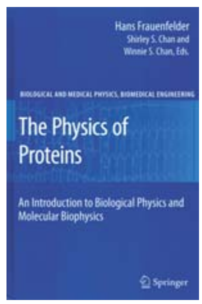
Theoretical Molecular Biophysics

Philipp O. J. Scherer and Sighart F. Fischer
Springer, New York, 2010. $99.00 (371 pp.). ISBN 978-3-540-85609-2

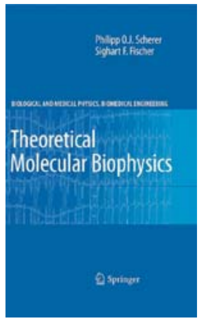
Since biophysics is a young science, its major emphasis has been on experiment rather than theory. However, theory is necessary to provide the broad outlook that welds experimental results into a cohesive picture; it may also suggest new experiments. Two new books should help reduce the theory deficit.

The Physics of Proteins: An Introduction to Biological Physics and Molecular Biophysics contains lecture notes by biophysicist Hans Frauenfelder; it is edited by Shirley Chan and Winnie Chan and has contributions from four physicists in the field: Robert Austin, Charles Schulz, Ulrich Nienhaus, and Robert Young. It appears to be written for advanced undergraduates and graduates in physics who are newcomers to biophysics and biochemistry. Frauenfelder completed his doctoral degree in 1950 at ETH Zürich, where he studied under Paul Scherrer, Wolfgang Pauli, and Gregor Wentzel. He then moved to the University of Illinois at Urbana-Champaign where for the next four decades he conducted research on the dynamics of proteins, measuring their response to a pulse of synchrotron radiation over broad ranges of temperature and time. Those experiments revealed the multiple, nonrigid configurations inherent in proteins and led him to appreciate their complexity. Since 1990 he has continued his research at Los Alamos National Laboratory.

Following the introductory chapters, the book discusses the three-dimensional structure and dynamics of proteins, particularly myoglobin and hemoglobin. The book builds from Frauenfelder's sketches and hand-drawn diagrams, which impart to the volume a personal touch, to its major theme: Frauenfelder's insight that protein structures undergo conformational transitions—proteinquakes—through substates of approximately equal energy in a rugged, multidimensional, conformational-energy landscape.



In a beautiful example of the interplay of theory and experiment, the discussion of electronically controlled reactions in the chapter on reaction theory gives an atom-by-atom account of the concerted motion of nuclei and electrons that occurs when carbon monoxide binds to the iron atom at the center of a hemoglobin molecule's heme group. Informative appendices cover thermodynamics, quantum chemistry, Mössbauer spectroscopy, nuclear magnetic resonance, and x-ray and neutron diffraction. The other contributors highlight some of the challenges in the field: "We have a long way to go" in deciphering the structural dynamics of the T4 lysozyme, Austin cautions on page 433. Readers are also encouraged in chapter 17, "Creative Homework: Dynamics and Function," to dig into the dynamics, processes, and functions of neuroglobin (Nienhaus) and of the folding of a polypeptide chain into a functional protein (Young). Each chapter closes with a list of references.



Some aspects of *The Physics of Proteins* left me puzzled. Although claiming interest in "a fundamental understanding of . . . essentially all proteins" (page 209), the book omits an important class of them—membrane proteins. In chapter 14, "Supercooled Liquids and Glasses," Frauenfelder asserts that "many properties of glasses and proteins are similar." But are there glassy proteins at physiological temperatures? Particularly perplexing were Austin's discussions of Davydov solitons in chapter 16, "Protein Quantum Dynamics?" In the theory part, Austin dismisses that model, asserting that "most biological polymers are insulators." However, that is true only for electronic conduction, not ionic conduction, an important mechanism in cellular respiration, information processing, and force generation. Also, in a chapter on water, Austin proves the nonexistence of ferroelectricity in ice but ignores ferroelectricity in liquid crystals and proteins.

Intended for graduate students, *Theoretical Molecular Biophysics* by Philipp Scherer and Sighart Fischer grew out of a biophysics course taught by the authors in the physics department of the Technical University of Munich. This well-organized book assumes familiarity with such mathematical objects as symmetry groups, the delta function, and raising and lowering operators. In the preface, Scherer and Fischer point out that "while the biologist uses mostly a phenomenological description, the physicist tries to find the general concepts to classify the materials and dynamics which underly [sic] specific processes." They also note that although biological systems exhibit "a certain amount of disorder," their functions, paradoxically, "are highly reproducible." The challenge of the book, which lists 132 references, is to "try to provide basic concepts, applicable to biological systems or soft matter in general."

A striking feature of *Theoretical Molecular Biophysics* is