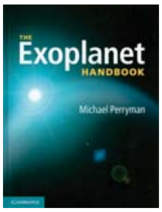
New and distant worlds, all in one place

The Exoplanet Handbook

Michael Perryman
Cambridge U. Press, New York, 2011. $80.00 (410 pp.).
ISBN 978-0-521-76559-6

Reviewed by Gregory P. Laughlin

An encyclopedist's goal, and an admirable one for any scientist, is to distill a vast and disparate collection of facts and observations into a coherent, encompassing whole.



A high point of such efforts was the work of Georges Louis Leclerc, Count of Buffon (1707–88), author of the *Histoire naturelle, générale et particulière*. Buffon's thorough, 44-volume synthesis of the 18th-century understanding of the geology and fauna of our planet was influential and widely read. One of the collection's most remarkable aspects was its groundbreaking scientific account of Earth's formation.

Now fast-forward to the complex world of today; the thought of codifying all of natural science into 44 volumes is a hopelessly quaint one. But for a scientific subfield, *The Exoplanet Handbook*, an encyclopedia of extraterrestrial worlds, is a worthy successor to Buffon's work. Its author, Michael Perryman, who served as scientific leader for the European Space Agency's highly successful Hipparcos Space Astrometry Mission in the mid 1990s, has written an excellent, startlingly complete snapshot of the current state of knowledge regarding extrasolar planets.

Before the mid 1990s, such a handbook would have been considered something in the realm of science fiction or an occasion for raised eyebrows. That's because the scientific community had been subjected to regular, spurious claims of the discovery of planets orbiting other stars. Famous examples include announcements starting in 1855 of a planetary companion to 70 Ophiuchi, a binary star system, and inaccurate projections, persisting until the 1970s, that one or possibly two Jupiter-like planets were harbored in Barnard's Star, a nearby red dwarf.

The first bona fide detection of an extrasolar planet was published in 1989 by astronomer David Latham and four colleagues. Latham's team used the Doppler radial-velocity technique to sense an object of at least 11 Jupiter masses on an eccentric 83.9-day orbit around HD 114762, a relatively nearby Sun-like star. However, given the poor track record of previous extrasolar planet claims, the discovery of an object orbiting HD 114762 did not generate excitement within the astronomical community.

In 1992 Aleksander Wolszczan and Dale Frail, using extremely accurate pulse-arrival timing methods, detected two terrestrial-mass planets with Mercury-like periods of 66.5 and 98.2 days orbiting the millisecond pulsar PSR 1257+12. That discovery was followed in 1995 by Michel Mayor and Didier Queloz's discovery of 51 Pegasi b, with a minimum mass roughly half that of Jupiter and a startlingly short 4.23077-day orbital period. Thereafter, the pace of discovery ballooned, as did our understanding of both the planetary census and the physical characteristics of alien worlds.

The Exoplanet Handbook is divided into two distinct segments: The first eight chapters focus on detection methods, and the last seven chapters are devoted to the physical characterization, formation, and evolution of the planets themselves and their host stars. The latter section is quite complete and will be of immediate utility to students or researchers entering the field. The first section is a thorough, authoritative, and evenhanded discussion that heightened my appreciation of the current detection-method landscape. It's remarkable that so many methods—including Doppler velocity, transit photometry, astrometry, pulse timing, gravitational microlensing, and direct imaging—have all successfully detected extrasolar planets in the past two decades. Together, those methods have enabled the discovery of nearly 800 well-characterized extrasolar planets; thousands more have been pinpointed by photometric monitoring with NASA's *Kepler* spacecraft.

Like any good encyclopedia, *The Exoplanet Handbook* has as its major strength its reference list, which cites more than 4000 papers. The list provides a near-complete snapshot of all the research that has taken place in the field in the past two decades. Furthermore, the references are deftly integrated into the text, which makes this volume an excellent point of departure for any researcher seeking to chart a new course of exoplanetary investigation.

Gregory Laughlin is chair of the astronomy and astrophysics department at the University of California, Santa Cruz. His research interests focus on the detection and characterization of extrasolar planets. He writes regularly at http://www.oklo.org about his work and about developments in the field.

The Idea Factory
Bell Labs and the Great Age of American Innovation

Jon Gertner
Penguin Press, New York, 2012. $29.95 (432 pp.). ISBN 978-1-59420-328-2

In *The Idea Factory: Bell Labs and the Great Age of American Innovation*, author Jon Gertner describes, in a new and compelling way, the inner workings of arguably one of the greatest industrial research organizations of the 20th century.

Gertner, who has written for the *New York Times Magazine*, traces the roots of Bell Labs primarily through a half dozen brilliant scientists and engineers and technically visionary leaders who gave birth to some of the defining communications and computer technologies of our time. Among those chosen were Mervin Kelly, the labs' innovative research director and, later, its president; William Shockley, co-inventor of the transistor; Claude Shannon, father of information theory and digital communications; and John Pierce, who envisioned communications satellites in the 1940s and instigated early work on cellular telephony and optical communications.

At the turn of the 20th century, during the era of great inventors such as Thomas Edison and Alexander Graham Bell, executives at the American Telephone and Telegraph Co—later AT&T—began to recognize the need for a strong technical organization that could enhance its competitive position in the emerging area of long-distance telephone communications. But the role of scientific and engineering disciplines, such as physics and electrical engineering, in the pursuit of industrial innovation was only beginning to be appreciated. Around 1915, AT&T gave University of Chicago physicist Frank Jewett the task of bringing in technical experts to develop amplifiers for the vacuum-tube repeaters that maintain signal strength along transmission lines. Jewett recruited Kelly, Harold Arnold, Harvey Fletcher, and other students of his friend physics Nobelist Robert Millikan. Those students understood the value of "a knowledge of the things and methods of science" and the need to "bring to bear an aggregate of creative force on any particular problem."

The success of the vacuum-tube repeater eventually led to the formation of Bell Telephone Laboratories in 1925 as a separate R&D arm. Kelly's early vision of an "institute of creative technology" hinged on hiring such brilliant minds as William Baker, John Bardeen, Walter Brattain, Pierce, Shannon, Shockley, and Charles Townes. Those scientists, and a few others, formed the nucleus of a research organization that also featured systems engineers and technology developers.

Through multiple interviews, particularly with some former Bell Labs executives, Gertner reveals many characteristics of a culture and institutional environment that spawned a large number of innovations. Bell Labs focused on the broad mission; motivated its researchers to continually strive for technology innovation; maintained an "end-to-end" business service as a matter of public trust; applied systems engineering thinking, which eased the integration of research and manufacturing; trusted its visionary and technically savvy leaders; recruited the "best and the brightest" researchers, who would not have to worry about applying for federal funding; and created an environment that encouraged long-term thinking and afforded its workers a "circumscribed freedom" that was at the same time "liberating and practical."

Unusual for a corporate lab, Bell Labs was a place where office doors were open and the boundaries between disciplines were porous: Theorist Bardeen had an office in the lab of experimentalist Brattain, and the two recorded data side by side when transistor action was discovered. It was also a place where Shannon wandered the halls on a pogo stick, vice president of research Baker sat and interacted with staff members in the large cafeteria, and Kelly asked the research staff to investigate "not what is known" but rather "what is not known."

In the last chapter of *The Idea Factory*, entitled "Echoes," Gertner asks the following: In a time of venture capitalists, open innovation, and highly successful information technology companies such as Apple, Google, and Facebook, is there a need for an organization like Bell Labs? Can we expect venture-driven companies, including ones reaping healthy profits, to invest in truly long-term research projects? Those are important questions for science policymakers as they debate the merits of different innovation models.

For answers, Gertner suggests looking beyond the information technology industry to such areas as the life sciences, which has the Howard Hughes Medical Institute's Janelia Farm Research Campus in Virginia, and clean energy, which includes energy innovation hubs championed by Steven Chu, a former Bell Labs researcher and the current secretary of the US Department of Energy.

In my view, we need new modalities of public–private partnerships to enable radical innovation for the public good. *The Idea Factory* is well worth delving into as a source of lessons learned in how to build forward-looking, innovative technology institutions.

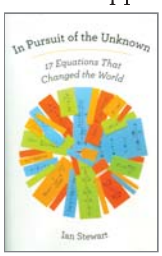
Venkatesh Narayanamurti
Harvard University
Cambridge, Massachusetts

In Pursuit of the Unknown

17 Equations That Changed the World

Ian Stewart
Basic Books, New York, 2012. $26.99
(342 pp.). ISBN 978-0-465-02973-0

Emeritus professor of mathematics Ian Stewart is a well-known and well-regarded writer on popular mathematics. As a testament to his outstanding expository skills, he succeeded Martin Gardner—a tough act to follow—in writing the Mathematical Games column at *Scientific American*. Stewart's new book, *In Pursuit of the Unknown: 17 Equations That Changed the World*, tackles an equally tough challenge.



"Equations that changed the world" is a phrase guaranteed to intrigue the sort of person who, if given a choice between the latest issues of PHYSICS TODAY and the *Economist* while trembling in the waiting room of a dentist, would pick the latter. That person may be intelligent and literate, but not a physicist, mathematician, or engineer.

I write that not because *In Pursuit of the Unknown* is a bad book—far from it, as I'll soon explain—but because the subtitle is likely to prompt a regular reader of PHYSICS TODAY to retort, "What do you mean, 17 equations? I can think of at least 50. Maybe even 75 if you give me until lunch!" Stewart, I'm sure, is well aware of that and writes (unfortunately, not until the end of the book), "It took a lot more than seventeen equations to get us where we are today." In comparison, Dana Mackenzie's *The Universe in Zero Words: The Story of Mathematics as Told Through Equations* (Princeton University Press, 2012) covers 24 equations, not all of which overlap with Stewart's. But given the reality of publishing, one can hardly fault Stewart, or Mackenzie, for not writing the 177 314–page book required to discuss every important equation.

In general, an assessment of equations to include would probably be 50% "No argument with that choice" and 50% "I wonder how that one made the final cut." In Stewart's collection, the first category includes the Pythagorean theorem (about which Stewart unfortunately repeats a tasteless joke that no teacher with any sensitivity would ever tell in lecture), Newton's inverse-square law, and Maxwell's equations. The second category contains the Navier–Stokes equations, Euler's formula for polyhedra, and the Black–Scholes equation (with which financial traders nearly destroyed modern banking). The wave equation, Fourier transforms, the second law of thermodynamics, $i = \sqrt{-1}$, and $E = mc^2$ are in the mix, too. Of course, my selection of which category each of those falls into is as eccentric as Stewart's. And that's my point. I can't help but wonder, however, how Boolean algebra's wonderful $1 + 1 = 1$, which is at the foundation of our modern digital world, failed to make an appearance. Perhaps it was too obvious.

Each equation gets its own chapter, which opens with the equation itself, accompanied by a helpful explanation of what each symbol means. Each chapter is written in Stewart's easy prose, which never fails to both educate and entertain. The chapters are populated by lots