

fore transformation, including electric and magnetic fields but not nuclear spins, covers two full pages with 32 distinct terms identified. The systematic evaluation of the matrix elements of such terms requires spherical-tensor techniques, which the authors develop from scratch and use extensively. By way of contrast, I searched in vain in Herzberg's book for the matrix elements of J_+ and J_- , which are fundamental operators in the spherical-tensor algebra.

After the authors develop the theoretical tools, much of the second half of the book is devoted to case studies of spectra of particular molecules. The studies are often described in terms of classic experiments that introduced some of the observational techniques. These case studies often show the authors' bias toward electric- and magnetic-field effects and hyperfine structure; not until chapter 10 (more than two-thirds of the way through the book) do readers finally reach the subject of pure rotational spectroscopy in a book on rotational spectroscopy!

Rotational Spectroscopy of Diatomic Molecules is carefully written and well produced. But a curious characteristic, partly responsible for the book's great size, is its repetitiveness. For example, the authors introduce the Euler angles twice, in chapter 2 and again in chapter 5, using exactly the same diagram. Spherical harmonics are defined in table 5.1 with standard phases, but they reappear for no apparent reason in table 6.1, with different phases. In the case studies, the matrix elements of terms often duplicate previous equations. The authors sometimes repeat steps in the algebra as though their treatment of each molecule had to be self-contained. The formulas are useful for their intended purpose, but to the uninitiated they look like opaque jumbles of Wigner $3j$, $6j$, and occasionally $9j$ symbols, with strange sign factors that only a devotee could love; it is difficult to see why they should be repeated.

A significant error in the book is in the authors' calculation of transition probabilities in chapter 6. The radiation density should be twice that given in the equation. As a result, the whole calculation is off by a factor of 2. In addition, the important statistical-weight factors are omitted from the calculation, but they appear later in chapter 10. The authors have the annoying habit of referring to some topic "as described elsewhere in this book," but with more than 1000 pages to choose from, such things are not easy to find.

Among other books covering similar subject material, the closest to

Brown and Carrington's book is possibly *The Theory of Rotating Diatomic Molecules* (Wiley, 1975) by Masataka Mizushima, which is less useful for the working spectroscopist and may be difficult to find in print. *Perturbations in the Spectra of Diatomic Molecules* (Academic Press, 1986) by Hélène Lefebvre-Brion and Robert W. Field—or its revised version, *The Spectra and Dynamics of Diatomic Molecules* (Elsevier, 2004), by the same authors—is more concerned with excited electronic states that are nearly degenerate with each other. Walter Gordy and Robert L. Cook's *Microwave Molecular Spectra* (Wiley, 1984) and Eiji Hirota's *High-Resolution Spectroscopy of Transient Molecules* (Springer-Verlag, 1985) contain chapters on similar subjects, but those books are not restricted to diatomic molecules.

Rotational Spectroscopy of Diatomic Molecules is a detailed, wide-ranging presentation of all kinds of spectra within a given electronic-vibrational state of a diatomic molecule. All serious spectroscopists should have a copy, and the book's price is reasonable. Besides, its sheer mass could be used to deter intruders.

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Stellar Alchemy: The Celestial Origin of Atoms

Michel Cassé (translated from French by Stephen Lyle)
Cambridge U. Press, New York,
2003. \$30.00 (242 pp.).
ISBN 0-521-82182-7

Many of us like to reflect on our childhood and family history. The search for origins covers not only human sensibility but also astronomical pursuits. In fact, "origins" is one of NASA's main themes and the title of one of its programs. In *Stellar Alchemy: The Celestial Origin of Atoms*, French astronomer Michel Cassé tells in his native language (translated by Stephen Lyle) some of the fascinating stories about how the elements in each of us came to be.

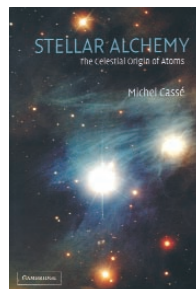
The lightest elements—including hydrogen (and its deuterium isotope), helium, lithium, beryllium, and boron—were formed in the first few hundred seconds or so after the Big Bang, an interval immortalized in Steven

Weinberg's book *The First Three Minutes: A Modern View of the Origin of the Universe* (Basic Books, 1977). Heavier elements, up to and including iron, were synthesized in stars. Elements heavier than iron come from fusion processes, called nucleosynthesis, that take place in supernovae, exceedingly violent events in our universe's history.

Cassé tells how the ideas of nuclear origins were put together. He even tells a personal story about his asking William Fowler, who shared in a Nobel Prize for his work on the origin of the elements, how he had linked up with Fred Hoyle to figure out basic paths for nucleosynthesis. Hoyle had found the fundamental idea of how to bridge an instability gap with beryllium to form carbon. Cassé describes how the work wound up in the fundamental paper B²FH, which stands for Margaret Burbidge, Geoffrey Burbidge, Fowler, and Hoyle. The paper, which shows the variety of paths needed for the formation of elements, appeared in *Reviews of Modern Physics* in 1957.

Deuterium is the only isotope that is uniquely formed in the period just after the Big Bang. Thus deuterium abundance reveals initial conditions because, unlike helium, for example, which is a common product of stars, it is not created in the subsequent eons. Cassé acknowledges the importance of determining the deuterium abundance, but he relegates it to his first lengthy, discursive appendix in the book. He writes that "deuterium holds the key to the mystery, but it is difficult to measure." My own work in the field deals with cosmic deuterium. Most recently, Jayaram Changelur, Donald Lubowich, and I tried again, without immediate success, to detect deuterium's fundamental spin-flip line at a 92-cm wavelength using the new Giant Meterwave Radio Telescope outside Pune, India. But values of the deuterium abundance from UV spectra and from radio observations of deuterated molecules, which need chemical interpretation, have elucidated light-element formation from this primordial nucleosynthesis.

Stellar Alchemy is for the general reader, although some parts of the text and some diagrams are complex. The author does not hesitate to give equations for fusion and decay processes. I think it is strange and rather off-putting to begin each chapter with a boldfaced set of vocabulary words and definitions. Chapter 1 begins with



18 such definitions; chapter 3, with 24.

I found the language in the book forced and stilted, as though the translator was literally rendering flowery French in a style to which English speakers are unaccustomed. John J. Cowan, who reviewed the book for *Nature* (25 March 2004, p. 369), concludes that “Cassé’s writing style, flowery and poetic and full of historical references, makes even the more technical material accessible to the general reader.” So I guess someone likes it—but I don’t. My dictionary gives a definition of “interpellate” as interrupting a European parliamentary debate, but I still don’t know what “interpellated by the telescope” means in Cassé’s book.

I also wish that Cassé, his translator, or editors had spelled “Kirchhoff” correctly by adding the second “h” in the name. Furthermore, the French version of the book came out in 2000, before the results of the *Wilkinson Microwave Anisotropy Probe*; the English version should have been updated to include them. The probe results show that the type of matter that is the subject of this book makes up only about 4% of the contents of the universe, with another 30% or so being dark matter and the remaining 66% in the form of an unknown called “dark energy.”

Other updating in the book should have included the name *James Webb Space Telescope*, which was mentioned only under its previous name, *Next Generation Space Telescope*. The current name has been around since 2002. Some results from the European Space Agency’s *INTEGRAL* gamma-ray telescope, whose 2002 launch is mentioned, should also have been covered in the book. Such omissions make one wonder what else has happened recently in the field. Also, in preparing an English edition, the author or editors should have included other international researchers in the footnotes and additions, not merely the names of French astronomers who work in the field.

In summary, the field of nucleosynthesis is very important, and it is inherently interesting to see how the elements in our universe formed. If you are willing to wade through the unwieldy prose in *Stellar Alchemy*, you will find a wealth of information about the atoms we are made of.

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Principles of Surface Physics

F. Bechstedt

Springer-Verlag, New York, 2003.

\$89.95 (342 pp.).

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Surface science is one of the frontiers of the physical sciences. It had its experimental origins in the 1950s and 1960s in the development of field ion microscopy and low-energy electron diffraction, both of which were in need of ultrahigh-vacuum conditions. In the late 1950s and early 1960s, the focus in surface science was on semiconductors, thanks to the rise of transistor-based devices. Those devices represented the first size-reduction technology, in which the device performance (speed, in the case of transistor-based devices) improved with the reduction in size. Other size-reduction technologies followed, including microelectronic circuitry and the magnetic disc drive. The pursuit of these technologies has made understanding atomic and electronic surface structure at the individual-atom level an imperative and demanded device fabrication with ever-improving spatial definition. The continuing importance of size reduction has led to the emerging research efforts in nanosciences and nanotechnology.

Another major focus of surface science has been surface chemistry. Studying the adsorption and ordering of atoms and molecules at surfaces, and determining their surface structure and bonding, have allowed exploration of the nature of the surface chemical bond. Improved knowledge of bond activation on transition-metal surfaces has led to studies of elementary reaction steps in heterogeneous catalysis. Chemical vapor deposition, etching, and epitaxial growth have been explored on the atomic scale. The industrial impact of surface chemistry research is exemplified by the development of the catalytic converter, used on automobiles since the 1970s, and the appearance of ubiquitous semiconductor devices based on heteroepitaxy.

Because most real-world applications of surfaces occur at high ambient pressure or at solid-liquid interfaces, new optical techniques and atomic probes have been developed over the past 10 years that permit one to study these surfaces on the atomic scale where information had not previously been available. As a result, electrochemistry and the orientation of molecules adsorbed at electrode

surfaces could be investigated on the molecular level as the external potential varies. Polymer and biopolymer surfaces have been studied, and changes of their surface structure and surface composition have been monitored as the interface shifts from air (hydrophobic) to water (hydrophilic). Since the human body can be thought of as a biopolymer–water interface with a monolayer of adsorbed protein, surface science now has the instrumentation available to explore molecular surface biology.

Principles of Surface Physics by Friedhelm Bechstedt focuses on formalistic treatment of surfaces and avoids dealing with experimental information accumulated over the past 40 years. It competently reviews the formulation of symmetry, surface thermodynamics, and elementary electron excitations. Surface reconstruction is treated only in the framework of semiconductor surfaces. The book concentrates

on the properties of the perfect surface; surface defects are considered in the last chapter as an afterthought. The lack of discussion about experimental developments and insights is a major deficiency of the book. The exciting new concepts of surface science—including adsorbate-induced restructuring; chemical bond breaking at surface defects and at rough, open surfaces; surface segregation in multicomponent systems; unique electronic and atomic structures of nanoparticles; the mobility of surface atoms; and molecules on and under the surface—are not mentioned. The impression Bechstedt conveys of the perfect surface is outdated. Thus I believe the intended readers of *Principles of Surface Physics*, solid-state physicists at the undergraduate or graduate level, are not getting a real picture of the richness, breadth, and depth of surface science.

Other books in the field—for example, John Blakely’s *Introduction to the Properties of Crystal Surfaces* (Pergamon Press, 1973); the series *Progress in Surface Science* (Elsevier); the series *Chemistry and Physics of Solid Surfaces* (Springer-Verlag), edited by Ralf Vanselow and S. Y. Tong; and the *Springer Series in Surface Sciences*—provide a great deal of information about modern surface science. And many other books cover various aspects of this multidisciplinary field, which ranges from the physics of semiconductor nanoparticles, to the selectivity of catalysts, to proteins monolayers at the atomic scale. Readers looking to

