books

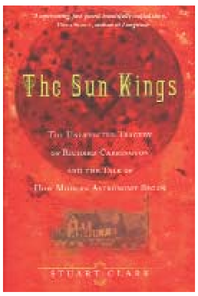
Royal revolutionaries of Victorian astronomy

The Sun Kings
The Unexpected Tragedy of Richard Carrington and the Tale of How Modern Astronomy Began

Stuart Clark
Princeton U. Press, Princeton, NJ, 2007. $24.95 (211 pp.). ISBN 978-0-691-12660-9

Reviewed by Richard C. Canfield

Stuart Clark's *The Sun Kings: The Unexpected Tragedy of Richard Carrington and the Tale of How Modern Astronomy Began* is a lively, informative discourse on the research that led to a discovery that in Victorian times was revolutionary: a cause-and-effect relationship between events on the Sun and Earth. Although the book is biographical, the science is not secondary: The characters and their research are skillfully interwoven in the narrative. The inclusion of the discoveries and personas of so many of the pioneers of Victorian astrophysics will make Clark's book an enjoyable and meaningful read for anyone, professional physicist and layperson alike, who has an interest in the roots of physics and astronomy.



Before the age of the "Sun Kings"—the Victorian astronomers who are the focus of the book—solar astronomy was strictly an intellectual pursuit. Nowadays, that field's liveliest branch is arguably the study of what contemporary geophysicists call space weather, the physics and phenomena of storms in interplanetary space and in Earth's magnetosphere, ionosphere, and outermost atmosphere that are caused by solar flares and coronal mass ejections. The practical relevance of space weather accrues from its threat to both spaceborne and ground-based technological systems and from the danger it poses to humans in space.

In setting the stage for his biography of the founders of Victorian solar astronomy, Clark, a writer for the European Space Agency who has a PhD in astrophysics, introduces the phenomena of space weather with a blow-by-blow account of the ferocious solar storms that took place around late October and early November 2003. He starts by discussing the radiation effects of those storms on astronauts aboard the International Space Station, passengers on airplanes flying polar routes, and instrumentation aboard scientific and weather satellites. This rhetorical device works well; it gives the reader a framework and motivation for understanding the final outcome of the convoluted and intensely personal research path taken by the pioneers of solar astronomy.

The author traces the development of the comprehension of the Sun–Earth connection from the 17th through 19th centuries, beginning with the telescopic observations of sunspots by Galileo in 1610. Key players in the 19th century included mathematician and Astronomer Royal George Biddell Airy and natural scientist Alexander von Humboldt. During the time that 18th-century astronomer William Herschel, the discoverer of the planet Uranus, was making his observations, it was well accepted that sunspots were indeed located on the surface of the Sun. But, interestingly, notions such as Herschel's that living creatures inhabited the Sun were not rejected out of hand.

The event that had the most impact on the solar astronomy that Clark chronicles was Carrington's telescopic observation in 1859 of a white-light solar flare. The sighting temporally coincided with an impulsive change in the direction of compass needles at a nearby magnetic observatory followed by an auroral display of extraordinary intensity, and with electrical arcs and the smell of scorched paint at telegraph stations. Although Carrington was famously conservative, cautioning that "one swallow does not make a summer," Clark rightly notes that the events were a tipping point for astronomy.

Clark is writing for a popular-science audience who will enjoy his lively and eminently readable account of the lives and scientific careers of those whose work furthered the understanding of the Sun–Earth connection. Moreover, all readers, professional physicists and interested laypersons alike, will appreciate that *The Sun Kings* is no dry, biographical tome. Clark's skillful writing weaves into his protagonists' research the aspects of their nonprofessional lives that so strongly influenced their work. That fact is captured in the book's rather embellished subtitle. Clark successfully presents the way a major subfield of modern astronomy began while introducing readers to one of its key players. Carrington led a hard life, punctuated by failed, turbulent relationships, professional and personal. Contemporary physicists will recognize that irrational and counterproductive rivalries, petty jealousies, and affairs of the heart were every bit as pervasive in the scientific life of the Victorian era as they are today.

Richard Canfield is a research professor in the department of physics at Montana State University in Bozeman. His interests include solar magnetism and flares, as well as solar eruptions and their interplanetary consequences.

An Introduction to Quantum Computing

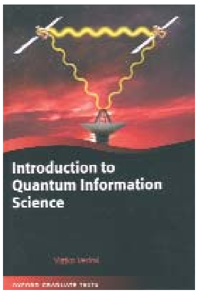
Phillip Kaye, Raymond Laflamme, and Michele Mosca
Oxford U. Press, New York, 2007. $150.00, $50.00 paper (274 pp.). ISBN 978-0-19-857000-4, ISBN 978-0-19-857049-3 paper

Introduction to Quantum Information Science

Vlatko Vedral
Oxford U. Press, New York, 2006. $70.00 (183 pp.). ISBN 978-0-19-9215706

There was a time when computer and information science appeared to be a discipline of pure logical reasoning, divorced from physics. Questions of what a computer could do and what resources would be needed to do it seemed to be largely independent of its physical construction. The connection between information and physics, thermodynamics in particular, has been developed during the past 50 years or so. A famous example of that relation was discovered by Rolf Landauer, who in 1961 showed that erasing, or otherwise irreversibly losing, a bit of information in a computer must dissipate at least kT ln2 of energy.

That idea, now called Landauer's principle, was succinctly summarized in his declaration that "information is physical," which has become a mantra in the fields of quantum information science and quantum computing. (See Landauer's article in PHYSICS TODAY, May 1991, page 23.) We now know that a computer that exploits the unique features of quantum mechanics can solve some problems more efficiently than any classical computer, a result that firmly links computer and information science to physics. Quantum information science, broadly defined, has expanded enormously over the past two decades, and numerous books on the subject at all levels have appeared, including Phillip Kaye, Raymond Laflamme, and Michele Mosca's *An Introduction to Quantum Computing* and Vlatko Vedral's *Introduction to Quantum Information Science*.



An Introduction to Quantum Computing covers a small subset of the topics in Michael Nielsen and Isaac Chuang's *Quantum Computation and Quantum Information* (Cambridge U. Press, 2000), which has become a standard text in the field. That tome, still relevant eight years after its publication, is probably too unwieldy for most undergraduates looking for an introduction to the field. In contrast, Kaye, Laflamme, and Mosca's book is very accessible. LaFlamme and Mosca are on the faculty of the Institute for Quantum Computing at the University of Waterloo in Canada and are well-known researchers in quantum information science; Kaye is a doctoral student at the university. Based on a course taught by the authors, the text is tightly focused on quantum computing and carefully leads the reader through Deutsch's, Shor's, and Grover's algorithms, among others. Coupled with the authors' careful exposition is a cadre of exercises, integrated into the text, that forms an important pedagogical aid. A series of exercises presented early in the book, for example, guide the reader to the existence of a universal set of quantum gates. For better or worse, in some places important results are simply declared as theorems without proof.

The authors do an excellent job breaking up Shor's factoring algorithm into pieces that students can easily digest. They take the approach—not original, but deftly presented—of reducing the order-finding problem at the heart of factoring to the problem of finding the eigenvalues of a unitary operator, delegating much of the work to the reader through exercises. The book contains a chapter on quantum complexity that is more formal than the rest of the text and may not appeal to some readers. However, readers who skip or skim that chapter will have little trouble digesting the remainder of the text.

Vedral's *Introduction to Quantum Information Science* is billed as a graduate text but is not really—it contains no exercises. Distilled from a series of lectures by Vedral, a professor of quantum information science at the University of Leeds in the UK, it is a bit uneven, both in the selection of topics and style of presentation. Sometimes more space is given to the algebra of a simple example than to a fairly abstract proof.

Most of the book focuses on quantifying quantum entanglement, the author's primary current research field, and quantum information by using entropic measures. That approach pervades his treatment of quantum computing, measurement, and error correction. Formal results are sometimes followed by clear discussions of analogies to thermodynamics. Error correction, for example, is cast in terms of swapping quantum states and entropy into environmental degrees of freedom. The book is a good, technical read, with many pithy or whimsical footnotes sprinkled throughout. Unfortunately, Vedral's text contains numerous typographical errors and notational ambiguities. Most are merely distracting, but some may lead to real confusion. In contrast, the few errors I found in Kaye, Laflamme, and Mosca's text are almost entirely inconsequential.

Both *An Introduction to Quantum Computing* and *Introduction to Quantum Information Science* would benefit from a stronger adherence to Landauer's dictum. If information is physical, discussions of quantum information need to be coupled with concrete examples of physical implementations. Although the fundamental results of quantum information science depend on the logical structure of quantum mechanics—unitary evolution in Hilbert space and, perhaps, the projection postulate—and not on any specific qubit implementation, neglecting experimental realizations is unwise. A novice reading Kaye, Laflamme, and Mosca's book, for example, might reasonably reach the conclusion that if there is a universal set of gates, clearly delineated quantum algorithms, and error-correcting codes on paper, then a large-scale quantum computer should be just around the corner. The reader should at least be given a glimpse of the challenges involved in making a robust controlled-NOT gate or performing a complete Bell-state measurement; both are primitives on the quantum information theorist's palette but are challenging to perform in the lab. The closest these books come to discussing experiments are brief mentions of idealized Mach–Zehnder interferometers. Remarkably, because of an algebra mistake, Vedral gets that example wrong—the photon exits the wrong way from the symmetric interferometer.

There is another, deeper reason experiments in this field deserve more attention. If researchers fail to construct a large-scale quantum computer, it may be because of some practical limitation, or it may be the sign of something more interesting. A spectacular, albeit speculative, possibility is that we find quantum mechanics breaks down, and there emerge some fundamentally new laws of physics and, by extension, of information.

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The Grid

A Journey Through the Heart of Our Electrified World

Phillip F. Schewe
Joseph Henry Press, Washington, DC, 2007. $27.95 (311 pp.). ISBN 978-0-309-10260-5

Electricity uniquely combines three attributes: It is crucial, even for minimally developed societies; fragile, in that prohibitive storage costs require production to equal use by the minute; and interconnected, because failure of one supplier to meet demand can black out half a continent. In *The Grid: A Journey Through the Heart of Our Electrified World*, Phillip Schewe, chief science writer at the American Institute of