

supported during the period in question; it simply (and regrettably) chose to focus on the shuttle and international space station. Shapiro further sees no reason why funding human exploration of Mars should conflict with worthy social goals, despite a price tag conservatively estimated at 25 billion dollars. In the end, then, *Planetary Dreams* is a reverie on what might be: elsewhere—if some certain future comes to pass, if some certain worldview turns out to be correct, if some budgetary genies materialize from the ether, if... It would be churlish to condemn dreams, but the conversion of dream to discovery requires hard facts and concrete plans that are not much in evidence.

Quo vadis astrobiology? Drury, Jakosky, and Shapiro each provide thoughtful parts of an answer, but none succeeds fully in capturing the excitement, promise, and deep uncertainties of nascent astrobiology. For that we must await the next wave of explanations, already starting to appear on bookshelves.

Astronomy in Prehistoric Britain and Ireland

Clive Ruggles
Yale U. P., New Haven, Conn.,
1999. 285 pp. \$65.00 hc
ISBN 0-300-07814-5

Behind Clive Ruggles's simple and geographically circumscribed title—*Astronomy in Prehistoric Britain and Ireland*—lies an exceptionally important, wide-ranging, and critical contribution to the field that has come to be called "archaeoastronomy." His professed aim is "to bring the wide range of people interested in prehistoric astronomy to a common starting point." His deceptively modest goal in fact hides a daunting project. This area of inquiry into the true significance of stone circles, "henges," isolated megaliths and other archaeological monuments that have been associated with prehistoric astronomy straddles archaeology, astronomy, and the often forgotten component of statistics, to mention only the main contenders. The very different prerequisites and approaches of these fields, as well as partial ignorance or selective use of them, have led to much miscommunication and many misunderstandings among the specialists whose paths intersect with prehistoric astronomy. A "common starting point" would indeed be first among

the desiderata for a field impaled, as Ruggles suggests, on C. P. Snow's "two (or three?) cultures."

Consistent with his aim, Ruggles's approach is at once foundationalist and pedagogical: What can we know with reasonable certainty about megaliths to which astronomical powers have been ascribed, if this knowledge is filtered through the best tools and insights that all three fields offer? And how can one demonstrate this common ground to the satisfaction of people from very different fields? Once trained in mathematics and astrophysics, Ruggles is now a senior lecturer in archaeology at the University of Leicester, UK, and therefore admirably suited to the cross-cultural task he envisions. Sprinkled throughout his chapters are not only many illustrations, maps, charts, and graphs, but also three categories of shaded one-to-two-page "boxes" that introduce the reader to the fundamental concepts of astronomy, archaeology, and statistics relevant to archaeoastronomy. Although these pedagogical capsules break up the chapters, they allow Ruggles to familiarize specialists in one area with the vocabulary, strengths, and limitations of the other two.

The tripartite structure surveys the entire field rather than any single archaeological monument or class of monuments. Part I ("Past Directions") combines a history of archaeoastronomy with a sharp critique of its pre-1980 conclusions and methodologies. This is passionate contemporary history, recounted by one of the most active participants in it. These early years, epitomized in Alexander Thom's concept of the monumental "observatories" distributed throughout the British Isles (*Megalithic Observatories*, Oxford, 1971) generated claims about astronomical alignments as precise as 1–2 arcmin. These amazing claims rested on the seemingly unimpeachable foundations of empirical fieldwork and statistics, the neglect of the archaeological context notwithstanding. As Ruggles demonstrates, however, such conclusions are derived unwittingly from selective alignment data that vitiated the non-randomness of Thom's statistics. A critical reexamination of this material (including massive new surveys of several hundred monuments) reintroduced much randomness into many alignments and effectively undermined Thom's claims for a high-precision astronomy, geometrical reasoning, a megalithic calendar, and a megalithic metric. Without under-

standing Thom's computations, many archaeologists already suspected as much, since such astonishing achievements clashed with the pre-literate culture inferred from the archaeological record.

For these colleagues in particular, Ruggles is at pains to argue that archaeoastronomy has changed. Part II ("Present Directions") draws on impressive empirical data from his own and others' fieldwork during the last fifteen years to show how. His context-sensitive examination of monuments in specific locales (notably three hundred West-Scottish recumbent stone circles, dozens of Irish axially oriented stone circles in Cork and Kerry, and dozens more Irish and Scottish stone rows) offers conclusions consistent with the methodological critique of Part I. The statistical analysis roughly correlates the overhead full moon with the orientation of the reclining stones found in the many Scottish circles, but shows no significant correlation in the axial stone circles.

Imprecise celestial alignments, therefore, guided the design of some monuments, but astronomy was arguably not the sole, or even the main, purpose of these monuments as a group. Indeed there are good reasons to doubt that alignments with the horizon were the dominant feature of these stone monuments. Against Thom's advocacy of a single megalithic astronomical culture, Ruggles uses his field data to reinstate the importance of local traditions and place-specific responses to the landscape, and, as always, to plead for attention to social and cultural context when drawing conclusions about the monuments.

In Part III (Future Directions"), Ruggles outlines a research agenda that avoids archaeological dismissals of archaeoastronomy (often based on pre-1980 work) and the older, archaeoastronomical fixation on decontextualized data. To the most diffident of his archaeologist colleagues, Ruggles presents a compelling case for the importance of questions about astronomical practices in ancient civilization. As he notes, the night sky was not only a crucial part of the natural environment of early civilizations, but virtually the only such element that we can reconstruct with great confidence. It would be rash indeed to turn one's back on such knowledge. Conversely, before the universalizing tendencies of his physical science colleagues, he pleads for sensitivity to the particular, the local, and the time-bound—and

for great caution before assuming that we can second-guess prehistoric responses to the sky.

And what about Stonehenge? Despite many disagreements, leading luminaries in the history of astronomy, archaeology, geography and archaeoastronomy concur in seeing Stonehenge as a cosmic monument. Yet Ruggles notes: "While we would not wish to dismiss ideas such as these without good reason, we also need good reason for continuing to support them." Such is the measure of his caution, skepticism, and deliberate judgment.

The book ends with extensive appendices of data from Ruggles's surveys, an account of data reduction, and indexes.

A short review cannot do justice to the richness, depth, or scope of a book that looks like a landmark in the investigation of megalithic monuments. Whether skeptics or enthusiasts, all specialists with a stake in this project will need to come to terms with Ruggles—and so should every lecturer who broaches the subject of prehistoric astronomy.

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The Odd Quantum

Sam Treiman
Princeton U. P. Press, Princeton,
N.J., 1999. 256 pp. \$24.95 hc
ISBN 0-691-00926-0

In the 1960s and 1970s, Princeton University's Sam Treiman was known as an experimenter's theorist. Through his publications, and especially his talks, he made the latest theoretical ideas accessible to all, and he pointed experimenters to the crucial measurements they needed to make. In this modest volume, *The Odd Quantum*, he tries to provide access to the quantum theory to a wider audience.

Perhaps not quite as wide an audience as the blurb on the book jacket promises—"popular science readers." Treiman's book presumes, rather, a reader comfortable with the full language of the calculus, including partial differential equations. It does not demand any skill at computation, and its derivations are largely algebraic, but it will lose any reader intimidated by, for example, Maxwell's equations in full vector notation or by non-commuting differential operators.

That said, the text is accessible to nearly all physical scientists and more than a few biologists or economists who might want to see the quantum theory with much of its full conceptual apparatus arrayed. It

might also appeal to a bright sophomore, in an introductory physics course, impatient for a glimpse ahead at what he or she will be learning a couple of years down the line.

The treatment is largely formal. The only major concession to intuition is the use of the Schrödinger formulation for the nonrelativistic theory, although enough of the Heisenberg/Dirac approach is exhibited to support the valuable lesson that physical theories contain truths that transcend their mathematical frameworks.

A work of this brevity is necessarily concise. In just one 22-page chapter, Treiman reviews the foundations of classical mechanics, electricity and magnetism, and relativity. Another short chapter covers the historical development of the "old" quantum theory. The narrative is too sparse to convey accurately the subtle interplay of theory and experiment that characterized that period.

As a rule, Treiman separates applications from the formal development, a pedagogically risky approach. For example, quantum tunneling and alpha decay are in separate chapters. But the applications are well chosen, ranging from the conventional particle-in-a-box to more daring examples, including qualitative treatments of the Lamb shift and of the Bohm-Aharonov effect.

A strong chapter on quantum statistics contains an excellent discussion of the reason that identical particles must be treated differently in quantum and classical statistics. It also draws the connection between Bose-Einstein condensation (BEC) and stimulated emission. But it is short on applications; it is not made clear why a BEC of Cooper pairs would have zero electrical resistance. Nor are lasers explicitly dealt with.

Treiman's discussion of the problem of interpreting the quantum theory is perhaps the strongest feature of the book. He rejects the conventional Copenhagen assertion that it is the process of measurement that converts quantum probabilities to observable actualities. He points out that this interpretation leaves the mystery intact by not telling us how the measuring apparatus forces a system to "decide," resting instead on a distinction between the microworld and macroworld that is difficult to defend. In a section on the Einstein-Podolsky-Rosen (EPR) paradox and its experimental realization through Bell's inequality, he correctly pinpoints locality as the key issue, and he concludes that "the EPR notion of physical reali-

ty is too demanding for the quantum world that we actually inhabit."

On the other hand, Treiman has little sympathy with Eugene Wigner's resolution of quantum ambiguity in the mind of the observer, finding it "hard to falsify but hard to build upon, and hard to swallow without leading to rank solipsism." He concludes: "At the end of the day, quantum mechanics remains both intact and puzzling." Treiman reiterates this in the final sentence of the book, in which (paraphrasing Richard Feynman) he exhorts the reader to accept this theory in all its queerness because "that's the way the world is."

In its penultimate chapter the book explores the "zoo" of subatomic particles, using a conventional historical development of the quark model from hadron symmetries. The final chapter is on quantum field theory. Unlike most popular treatments of the subject, this one does not simply introduce Feynman diagrams but also constructs a simple "toy" quantum field—a scalar field with mass. Despite the abstract nature of this approach, Treiman's presentation is remarkably easy to follow.

This book can perform a great service by opening the quantum theory to a broader range of science professionals, many of whom now use its results without being fully aware of the concepts from which they arise.

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Reason Enough to Hope: America and the World of the Twenty-first Century

Philip Morrison and Kosta Tsipis
MIT Press, Cambridge, Mass.,
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ISBN 0-262-13344-X

Alfonso X ("the Wise"), King of Castille and Leon, is noted for his great academic work of law, the *Siete Partidas*. Although he was not a very successful ruler, he thought so highly of his own wisdom that he once commented on Ptolemaic astronomy, "Had I been present at the creation, I would have given some useful hints for the better ordering of the universe."

Some of that flavor of Alfonso comes through in *Reason Enough to Hope*, by physicists Philip Morrison and Kosta Tsipis, a tightly reasoned argument for the better ordering of human society. Although the authors are physicists, verbal eloquence