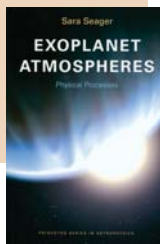


The air up there

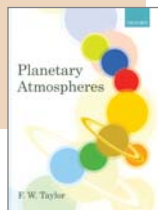
Exoplanet Atmospheres Physical Processes

Sara Seager
Princeton U. Press,
Princeton, NJ, 2010.
\$45.00 paper
(243 pp.).
ISBN 978-0-691-14645-4



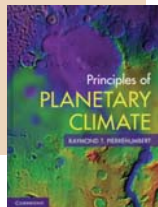
Planetary Atmospheres

F. W. Taylor
Oxford U. Press,
New York, 2010.
\$99.50 (296 pp.).
ISBN 978-0-19-954742-5



Principles of Planetary Climate

Raymond T.
Pierrehumbert
Cambridge U. Press,
New York, 2010.
\$81.95 (652 pp.).
ISBN 978-0-521-86556-2



Reviewed by Peter Gierasch

In recent years, astronomers have discovered more than a thousand extra-solar planets (exoplanets) or high-probability candidates. And increasingly, the astronomy and broader scientific communities are showing interest in climate and atmospheric conditions, which determine whether a planet can support life. The three books reviewed here provide important background for studying the atmospheres of planets inside and outside our solar system. Each takes a different approach and each will be of interest to students and nonspecialists who want an undergraduate-level treatment of problems in atmospheric and climate science.

Sara Seager's *Exoplanet Atmospheres: Physical Processes* is organized around

the concepts of traditional atmospheric science, which are used as background for the primary topic. Fred Taylor's *Planetary Atmospheres* gives a wonderful survey of atmospheres in our own solar system and does an excellent job of identifying open questions in planetary climate science. Although Raymond Pierrehumbert has worked on exoplanet climate theories, his book, *Principles of Planetary Climate*, is primarily about Earth, with frequent comparative references to Mars and Venus.

Exoplanet Atmospheres offers the appealing viewpoint of an astronomer whose enthusiasm is directed outward and who sees the subject as broad, with our solar system as only one example. It is reminiscent of the planetary science texts from a few decades ago, when knowledge of the planets was limited but excitement was growing as the first spacecraft missions were carried out. The choice of topics is wide: radiation, basic climate concepts, and even a bit of dynamics are discussed (although oceans are not included). The book's finest parts are the material sprinkled throughout concerning exoplanets and stellar environments that host such systems. Seager has thought carefully about methods of determining the climate and chemical composition of distant-planet atmospheres. She clearly conveys the difficulty of collecting information from a relatively tiny planet located in the immediate neighborhood of a glaringly bright star.

At 243 pages, Seager's text is the shortest of the three, and in some cases its treatment is compromised by the constraint of brevity. Students will be confused by the cloud formation discussion, which seems to suggest that the associated latent heat will be derived from first principles. Also, Seager's use of astronomical conventions in greenhouse gas calculations may obscure their underlying simplicity. But those are small matters. The important background material needed for the exoplanet discussion is all there.

Planetary Atmospheres, the most traditional of the group, presents a nice survey of solar-system atmospheres, confined to those for which we have detailed data. In nine chapters, Taylor provides comprehensive coverage of topics in atmospheric science—though the text does not discuss the mesoscale and the

boundary layer. I especially liked chapter six—"Atmospheric composition and chemistry"—for its clear presentation of current unanswered questions.

Two of this book's main strengths are the historical asides tracing the development of ideas through the decades (and in some cases, centuries) and the explanations of the instruments used to gather information. Taylor led the team that built the IR instrument that flew on NASA's *Pioneer Venus Orbiter* so he is well qualified to discuss hardware issues. He also includes an excellent description of seasonal and long-term changes in the two Mars polar ice caps, though he only briefly discusses theories of polar changes caused by obliquity variation.

My chief disappointment with *Planetary Atmospheres* was that with a page count of 296, it had little room for depth. Also, the book's presentation sometimes makes it apparent that the material originated from lectures, and it may cause students to be confused in places. For example, the troposphere is referred to as adiabatic on pages 27 and 95, but on page 171, probably from a lecture on a different day, the troposphere is crucially sub-adiabatic. And although the general production quality is excellent and the cover art pleasing, some small mistakes were made: The standard atmospheric-science complaint about typefaces that make the Greek ν indistinguishable from the italic v applies, and in my copy the table of contents is reprinted in place of the last 10 pages of the final chapter.

At 652 pages, Pierrehumbert's *Principles of Planetary Climate* is unfettered by space limitations. This work is a triumph. The writing is clear, and the topics are made more compelling by cross-referencing of related subjects. I found the book hard to put down. It focuses on fundamental concepts and lays them out thoroughly and in an orderly fashion. The student builds an understanding by solving problems of increasing complexity—the core of the book, in my view. The first chapter develops background perspective by reviewing terrestrial paleoclimate, and the second chapter reviews thermodynamics, which is always useful as background in atmospheric science. The major emphasis of the rest of the book is on radiation and heat balances.

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Principles of Planetary Climate avoids advanced mathematical techniques. To make it possible for the student to work realistically messy problems, along with the book, Pierrehumbert has prepared software and data files for numerical experiments. Most of the modeling is one-dimensional and therefore amenable to numerical investigation with simple programs. The problems are excellent. The presentation of radiation balance and the greenhouse effect in this book is the best I have seen. Obtaining gas absorption spectra—usually the show-stopper for teaching radiative balance and greenhouse effects—is aided by web-links to the high-resolution transmission molecular absorption database (HITRAN) archived by the Harvard-Smithsonian Center for Astrophysics. The included software also contains strategies for performing calculations with HITRAN. The range of behaviors that vertical heating profiles can display is exhaustively, authoritatively, and yet playfully explored, with each case presented as a puzzle to be enjoyed.

Pierrehumbert is an expert in the field of fluid dynamics. Knowing that, I looked forward to the book's last chapter, "A peek at dynamics." Sadly, the title is accurate. The author seems to have run out of steam just when he was positioned to illuminate the most difficult subject in climate studies. A treatment of dynamics with the depth and thoroughness of the radiation chapters would have been a service to the community. Perhaps we will see it in future editions.

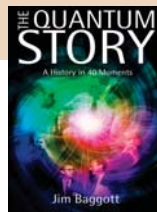
Principles of Planetary Climate presents atmospheric science as it is derived from first principles and thus lays the groundwork needed to move on to exoplanets, where it would be highly risky to assume that properties can be understood from solar-system experiences. Indeed, I was fortunate enough in 1965 to take a course in climate science from Jule Charney, a giant in the field of atmospheric dynamics, and I recall his warning that "nothing is predicted in this field. Phenomena are observed, then rationalized." One striking example from our own solar system is Venus; even the gross character of the general circulation was unpredicted and unknown until observations surprised astronomers in the 1960s.

All three books raise a question about the exoplanet excitement. Climate study of distant planets will require details of circulation and atmos-

pheric structure far beyond present observational capabilities. Will Charney's warning apply, or are we now better at predicting phenomena? Either way, these texts on planetary climate and atmospheres provide a broad, exciting, and useful perspective on the exoplanet revolution in astronomy.

The Quantum Story A History in 40 Moments

Jim Baggott
Oxford U. Press, New York, 2011.
\$29.95 (469 pp.).
ISBN 978-0-19-956684-6



Both history and popularization of science are essential for public understanding, but the relationship between them is akin to Niels Bohr's complementarity. Books that attempt to present scientific ideas in a straightforward manner often simplify historical issues to the point of distortion. On the other hand, attempts at maximum historical accuracy unnecessarily complicate the task of popularization since original and now-accepted interpretations rarely coincide.

In *The Quantum Story: A History in 40 Moments*, Jim Baggott achieves a balanced synthesis between both approaches while avoiding the above extremes. His primary goal is to explain, using historical and biographical vignettes, the contemporary state of quantum theory to nonspecialists who understand basic physics. Baggott has a talent for elucidating scientific ideas, including some of the latest sophisticated developments. Quantum physicists and professional historians of physics will also find much novel in his presentation, though they might disagree with him in places.

The book encompasses two rather different quantum stories under one cover. The first, more expected narrative presents the key steps on the road to quantum mechanics—from the 1900 Planck formula to the 1926 Schrödinger equation, interpretations leading to the uncertainty relation and complementarity, and the series of debates between Albert Einstein and Bohr that culminated with the 1936 Einstein-Podolsky-Rosen paradox. With lesser attention to the middle decades of the century, *The Quantum Story* proceeds to more recent conceptual developments involving Bell's inequalities, entanglement, and decoherence.

In comparison with Baggott's earlier book, *The Meaning of Quantum Theory: A Guide for Students of Chemistry and Physics* (Oxford Science, 1992), this edition adds some of the latest experiments but also shifts the tone of conclusion. The 1992 work praised quantum dissidents whose doubts about the Copenhagen interpretation had opened new theoretical and experimental questions and made several competing interpretations possible. Today, the author appears less interested in the alternatives: David Bohm's hidden-variables approach is still explained at length, but the many-worlds interpretation is discussed only briefly, and the more realistic ensemble interpretation is not mentioned at all. Baggott seems more satisfied with the simple lesson that quantum mechanics is "spooky" and involves some "weird" action at a distance; he does not mean to criticize but rather expects such words to please today's general audiences.

The book's second story goes beyond the continuing struggle to understand quantum mechanics's murky foundations and discusses its subsequent applications and developments. Here the author faces a daunting task because quantum physics has branched out into a number of fields, each with its own set of basic concepts. Anyone trying to represent the richness of this diversity must make difficult choices. Baggott is very good at explaining the topics he selects, but he seems completely unreflective about the rather narrow road chosen. He focuses on quantum field theory and the standard model of particle physics, while practically ignoring condensed matter, nuclear physics, astrophysics, quantum optics, and complex systems. Selected episodes center almost exclusively in the Anglo American world, with little attention given to the international character of quantum physics and important developments that took place in Calcutta, Moscow, Osaka, Rome, São Paulo, and Trieste.

Even when dealing with quantum fields, Baggott skips the theory's crucial founding stage and proceeds directly to the second act, which begins with renormalization and ends with W and Z bosons and superstrings. Some of the most fundamental quantum concepts thus remain unexplained, including the very idea of a quantized field, advocated by Pascual Jordan; antiparticles, predicted by Paul Dirac; the loss of individuality, uncovered by Satyendra Nath Bose and Paul Ehrenfest; quasi-