ASTROBIOLOGY
Volume 11, Number 1, 2011
© Mary Ann Liebert, Inc.
DOI: 10.1089/ast.2010.1229

Book Review

How to Find a Habitable Planet

*Reviewed by C.H. Lineweaver**

How to Find a Habitable Planet, by James Kasting, Princeton University Press, Princeton, NJ, 2010, 326 pp, ISBN: 978-0-691-13805.

INSTEAD OF DIVING into the Intergovernmental Panel on Climate Change Reports, astrobiologists interested in the physics behind global warming could start with Jim Kasting's new book, *How to Find a Habitable Planet.* Kasting not only describes how to find another habitable planet but also clearly explains the long-term evolution of terrestrial planet atmospheres. This is the long-term context needed to understand short-term global warming. Kasting explains the behavior of terrestrial planet atmospheres on billion-year timescales and shows us how, over the long-term on Earth, greenhouse gases come and go and the increasing luminosity of the Sun eventually humidifies the stratosphere, where H_2O is photolyzed and lost to space. Thus, the evolution of the Sun produces a leak in Earth's hydrological cycle that eventually sinks the boat of life.

In blurbs for this book, NASA Ames astrobiologist Chris McKay wrote "I learned several new things from this book," while MIT's Sara Seager wrote "everything you need to know about habitable worlds." As in any dialectical marketing scheme, the truth is in the middle. If you read this book you will learn more than "several new things" but certainly not "everything you need to know about habitable worlds."

Among the new things you might learn are that the Sun's luminosity increases about 1% every 100 million years; that methane, not ammonia, is the greenhouse gas of choice that most plausibly solves the faint early Sun problem; that tropospheric cold traps keep stratospheres dry. You might learn how to distinguish flashflood outflow channels on Mars from runoff channels due to ground water sapping; that Rayleigh scattering is proportional to λ^{-4} and why this explains how high CO_2 abundance acts as an anti-greenhouse gas by increasing Earth's albedo at short wavelengths; or how the Snowball Earth hypothesis is based on equatorial dropstones, diamictites, and cap carbonates from 710 and 630 million years ago. You might also learn the strengths and weaknesses of the various techniques for finding exoplanets and the important difference between a false positive and a false negative.

Kasting writes with the pace and authority of having taught this material many times to undergraduates at Pennsylvania State University. During a Jet Propulsion Laboratory sabbatical he compiled his lecture notes into this book and included the most important insights garnered from NASA Terrestrial Planet Finder meetings in 2004–2005. The extensive set of bibliographic notes are just what the overburdened academic needs to direct an enthusiastic but misinformed classroom of astrobiology students. Kasting has found and organized the essential references that will guide the beginner. For example, for a treatment of the Milankovich cycles, he leads the reader to Imbrie and Imbrie (1979) *Ice Ages: Solving the Mystery.* So much information is clearly dispensed that it is a pleasure to read. The digressions in the $\sim$100 footnotes provide some relief when the text seems too simple. The book includes 8 pages of color figures and an impressive 18 pages of bibliographic notes.

In addition to providing an excellent teaching resource, the book has much to offer to the seasoned astrobiologist. In chapter 10, Kasting describes, with authority and familiarity, the history of circumstellar habitable zone research. He traces the increasingly sophisticated research on the circumstellar habitable zone as it moves from Harlow Shapley's (1953) "Liquid Water Belt" to Hubertus Strughold's (1953–1955) "Ecosphere of the Sun" to the work of Huang in 1959–1960 to Dole's (1964) *Habitable Planets for Man.* Kasting describes how Hart (1978–1979) inappropriately used global glaciations to set the outer boundary of his habitable zone (we now know that we have probably lived through several such Snowball Earth episodes). Kasting reviews and extends the oft-cited habitable zone research of Kasting *et al.* (1993). He compares the atmospheric evolution of Venus, Earth, and Mars—a comparison that helps provide constraints on the inner and outer boundaries of the habitable zone. He describes how the increasing luminosity of host stars leads to the concept of a continuous habitable zone, and he gives us the pros and cons of habitable zones around M stars. The work of Franck *et al.* (2000a,b) on the continental-crust-dependent habitable zone is also discussed.

In several chapters Kasting describes climate models and their dependence on a zoo of feedback mechanisms: stabilizing negative feedback, runaway positive feedback, feedback at different timescales. Some feedback loops involving the same components act in different directions on different timescales. CO_2 seems to be linked to all kinds of complicated feedback. Trying to make a prediction based on a short-term positive feedback superimposed on a long-term negative feedback sounds as confusing and nonlinear as parenting a teenager. Kasting articulately walks us through this minefield and points out some instructive exceptions to this unpredictability. The buildup of CO_2 from ongoing

*Research School of Earth Sciences, Australian National University, Canberra, Australia.

volcanism pulled Earth out of global glaciations and produced cap carbonates that, in hindsight, were to be expected.

In 2000, Ward and Brownlee published a contagious book entitled *Rare Earth*. Unfortunately, it contained much misleading material. Chapter 9 of Kasting's new book and Kasting's (2001) review of *Rare Earth* provide detailed, thoughtful, and diplomatic antidotes.

The current book does not, however, avoid controversy. One of the most interesting ideas that Kasting flirts with is the Gaian question (Lovelock and Margulis, 1974; Lovelock, 1979): does a planet need to be inhabited to be habitable? What if "only inhabited planets would be habitable" (p 156)? It may be the case that the only way to maintain habitability is through being inhabited. In other words, one of the main ingredients in trying to figure out the habitable zone may be whether the planet is inhabited. Perhaps life can temporally and spatially extend the habitable zone by controlling atmospheric gases. It may be the case that Gaian feedback is what keeps a planet habitable. What if methanogenic archaea pumped up greenhouse methane (solving the faint early Sun problem), then cyanobacteria produced oxygen (removing the methane), and the long-term decline in CO_2 is a Gaian mechanism to cool the planet in the face of increasing solar luminosity? Ongoing habitability may depend more on the emergence of life and on the biological evolution of such global homeostatic mechanisms than on the increasing luminosity of the Sun, the mass of the planet, or the abiotically determined composition of the atmosphere. If Gaian mechanisms are largely responsible for keeping a planet habitable, then habitable planets will be harder for us to describe physically, and therefore it will be harder for us to know what to look for.

Kasting does, on the other hand, avoid the issue of the origin of life and the question: what is life? If habitability largely depends on whether life has managed to emerge on a planet, then this avoidance is the Achilles' heel of the book. There is not even a hint of doubt or a metaphysical digression on the difference between life as we know it and life elsewhere. This avoidance could be the responsible position of an academic who realizes that we know too little to say very much. But if there is a Trojan horse or a Pandora's box within the solid walls of our reasoning, then the danger should be acknowledged.

One of the most suspect of Kasting's assumptions is that life on any particular planet either exists or does not. This is like assuming that either a bird has a wing or it does not—either an organism has a brain or it does not. The study of the evolution of brains or any other biological structure shows that such black-or-white thinking is misleading. A distributed network of nerves (like that in a jellyfish) evolves into a notochord with a few knots in it, then into a bulge of tissue behind the eyes. The belief that either there is a fire or there is not, or that a creature either has eyes or does not (ignoring the possibility of eye spots or photosensitive pigments) is pre-Darwinian. The belief that there either is or is not life may be similarly naïve, yet Kasting apparently works within this dichotomy.

Kasting also seems to subscribe to Christian DeDuve's "life is a cosmic imperative" without bothering to justify this subscription. He also subscribes to Carl Sagan's "optimism" about the existence and political correctness of extraterrestrial beings, again without justification. "I am one of those people, who like Carl Sagan, would like to believe that life is widespread in the universe" (p 173). The hope that intelligent aliens exist should not be called "optimism." It should be recognized as a potential bias in our research. As astrobiology makes progress, unsubstantiated hopes should play an ever smaller part of our science.

Jim Kasting is a self-identified Trekkie who takes Star Trek's prime directive seriously. That directive—"Do not interfere with alien cultures"—makes him hope to find habitable planets that are uninhabited, so we won't displace any other life-forms. There is a certain irony here, as Kasting himself might acknowledge: if life plays an important role in habitability, then habitable, but uninhabited, planets may not exist.

In many ways, Kasting's book is like Barrie Jones' (2004) *Life in the Solar System and Beyond*. Both are written at a level between *Scientific American* magazine and a good review article. But Kasting's book is more useful for academics because it is so well referenced. If you are interested in a much more detailed mathematical treatment of exoplanet atmospheres try Sara Seager's new book *Exoplanet Atmospheres: Physical Processes* (2010), which should become the Rybicki and Lightman (1985) for exoplanets.

In *How to Find a Habitable Planet*, Kasting is no inspirational Sagan or visionary Lovelock or poetic Margulis. But the book informs us with authoritative clarity and simple straightforward arguments that make sense.

References

Franck, S. *et al.* (2000a) Determination of habitable zones in extrasolar planetary systems: Where are Gaia's sisters? *J Geophys Res* 105(E1):1651–1658.

Franck, S. *et al.* (2000b) Habitable zone for Earth-like planets in the solar system. *Planet Space Sci* 48(11):1099–1105.

Jones, B.W. (2004) *Life in the Solar System and Beyond*, Springer-Praxis, Chichester, UK.

Kasting, J.F. (2001) Peter Ward and Donald Brownlee's "Rare Earth." *Perspect Biol Med* 44:117–131.

Kasting, J.F., Whitmire, D.P., and Reynolds, R.T. (1993) Habitable zones around main sequence stars. *Icarus* 101:108–128.

Lovelock, J. (1979) *Gaia: A New Look at Life on Earth*, Oxford University Press, Oxford, UK.

Lovelock, J. and Margulis, L. (1974) Atmospheric homeostasis by and for the biosphere: the gaia hypothesis. *Tellus* 26:2–10.

Rybicki, G.B. and Lightman, A.P. (1985) *Radiative Processes in Astrophysics*, Wiley-VCH, Weinheim.

Seager, S. (2010) *Exoplanet Atmospheres: Physical Processes*, Princeton University Press, Princeton, NJ.

Ward, P.D. and Brownlee, D. (2000) *Rare Earth: Why Complex Life is Uncommon in the Universe*, Springer-Verlag, New York.

Address correspondence to:
Charles H. Lineweaver
Planetary Science Institute
Research School of Astronomy and Astrophysics
Research School of Earth Sciences
Australian National University
Canberra, Australia