books

Demotion commotion in outer space

Is Pluto a Planet?

A Historical Journey Through the Solar System

David A. Weintraub
Princeton U. Press, Princeton, NJ, 2007. $27.95 (254 pp.).
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Reviewed by William F. Bottke

Few topics in planetary science have ignited as much public debate and outright acrimony as the recent decision by the International Astronomical Union (IAU) to revoke Pluto's planetary status. The raw emotion behind that decision is reflected in the fact that being "plutoed," defined as "demoting or devaluing someone or something," was chosen as the 2006 Word of the Year by the American Dialect Society. This kind of fervor makes David A. Weintraub's *Is Pluto a Planet?: A Historical Journey Through the Solar System* particularly timely in that it provides some much-needed perspective on the battle over the meaning of the term "planet," a battle that, as we often forget, has been going on as long as astronomy itself.

In *Is Pluto a Planet?* Weintraub, a professor of astronomy at Vanderbilt University in Tennessee, uses historical examples to show that today's debate has much of the same flavor as past astronomical arguments, with observations continually presenting challenges to planetary orthodoxies. The author's approach makes some well-trodden facts, such as the switch from a Ptolemaic geocentric cosmology to a Copernican heliocentric one, considerably fresher than would otherwise be the case.

An important historical theme that resonates in the current debate can be found in the reaction to the early discoveries made using telescopes. The astronomers of antiquity had several opportunities to greatly expand the membership of the planetary club and, in fact, did so after the first few satellites and asteroids were discovered. As their knowledge increased, however, they decided to maintain the cachet of planethood by inventing new classifications for objects that were too small or too numerous, or had orbits that were simply too different from those of the established planets.

That history sets the stage for Pluto's odyssey, which mimics that of Ceres in the asteroid belt. Both were originally designated planets because they were thought to be massive objects in locations predicted by theory. Their planetary status was then questioned when they were found to be low in mass and part of a belt of objects. In the case of Pluto, the IAU debate was triggered by the discovery of multiple large objects beyond Neptune—some nearly Pluto-sized and one, Eris, larger than Pluto. So things could not remain as they were. Astronomers were left with several unpalatable choices: They could create numerous new planets, demote Pluto, or generate a convoluted or arbitrary definition that maintained the status quo.

Regarding the question in the book's title, Weintraub hedges somewhat but ultimately favors the retention of Pluto as a planet. His decision is primarily based on the idea that planets should be objects whose gravity is large enough to crush them into spherical objects. The downside, as acknowledged by Weintraub, is that the "one size fits all" solution is not very robust. Many satellites fit the above criterion, some objects are round because they have been heated by short-lived radiogenic nuclides, and it is difficult to know what to do with objects bordering on a diameter threshold that can be as low as 400 km. For the latter, there may be hundreds of objects on heliocentric orbits that fit the definition.

The IAU's definition of a planet came out too late to be extensively explored in Weintraub's book. That is a pity, given its importance and how unskillfully it was explained to the public immediately after the tumultuous 2006 IAU meeting in Prague. As a participant in the IAU debates, I can say that although the process was imperfect, the conclusions reached by researchers were similar to those made by their predecessors: There was general reluctance to radically depart from traditional classifications, and a messy problem was cleaned up by the creation of a new category of objects called "dwarf planets."

Dwarf planets, which are not planets, define mid-sized objects like Pluto, Eris, and Ceres. The smallest ones are those that pass the roundness test described above while the largest ones are determined by the effect they have on the surrounding solar system. According to the IAU, a true planet placed among a large number of planetesimals in orbit around the Sun would accrete or eject them within the age of the solar system. That definition includes Mercury through Neptune, which dominate their own regions of space, and excludes Pluto, which is in the Kuiper belt. The reader should note that the IAU's stance is not the conclusion reached by Weintraub.

Putting this dilemma aside, there is much to recommend in *Is Pluto a Planet?* Weintraub's history of the term "planet" is well told and interesting, and the narrative successfully walks readers through many of the pros and cons of different planet definitions. It puts the current debate into context and demonstrates how the acceptance of the new over the old in astronomy is driven or deterred as much by human foibles as by new information; the process is rarely the logical, dispassionate one portrayed in high-school textbooks.

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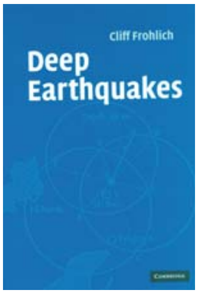
Deep Earthquakes

Cliff Frohlich
Cambridge U. Press, New York, 2006. $150.00 (573 pp.).
ISBN 978-0-521-82869-7

A labor of love by a dedicated researcher with a passion for the topic, *Deep Earthquakes* by Cliff Frohlich is unusual in its combination of breadth, depth, and tone. The intended audience



is broad—from specialists on deep earthquakes to geophysics researchers and graduate students to scientifically literate nonscientists. The book succeeds in offering results and explanations that are up-to-date and, though occasionally technical, still accessible. And I know of no other text devoted to deep earthquakes, or even one that treats them in depth.

Earthquakes in general occur in subducting slabs down to about 670 km below Earth's surface, but those that occur below 50 km present a seismological puzzle. Eighty years after their discovery, deep earthquakes remain mysterious—that is, researchers still do not understand the physical processes behind the seismic signals that have delivered most of the current knowledge of Earth's interior structure. Brittle failure and frictional sliding, the processes that generate shallow earthquakes, are strongly inhibited below depths of about 50 km by the intense stresses produced by the great weight of overlying rock, while ductile flow and deformation are prompted by the high temperatures of depth.

Over the decades scientists have suggested numerous mechanisms for deep earthquakes, including dehydration embrittlement, transformational faulting, thermal shear instability, and frictional melting. But whatever mechanisms operate in those inaccessible depths, the seismic signals emitted indicate sudden, sharp failure and differ only subtly from those of shallow earthquakes, which we geophysicists think are better understood. The research terrain is necessarily interdisciplinary, since the physics of deep earthquakes is related to the disciplines of seismology, geodynamics, and mineral physics through several physical processes, including phase transformations in mantle minerals, mantle circulation, plate tectonics, formation and hydration of the oceanic crust, and subduction of sediments and water.

Frohlich is associate director of the Institute for Geophysics at the University of Texas at Austin. A well-known seismologist with particular expertise in deep earthquakes and global seismicity, he has written a score of papers on deep earthquakes, focusing particularly on their statistics and the geometrical orientation of the seismic sources. He explains that as a graduate student at Cornell University, he "imprinted on deep earthquakes" in the way a duckling imprints on its mother, following her relentlessly. Frohlich admits he has remained obsessed with the topic.

Deep Earthquakes is a lengthy volume, enriched with numerous black-and-white figures, many from current literature and some created expressly for the book. The casual, sometimes quirky tone is unusual for a scientific narrative but refreshing and appropriate for the intended broad audience. All aspects of the topic are covered, some more thoroughly than others, and there is an emphasis on statistical significance throughout. In addition to long chapters on the discovery, properties, physical mechanisms, and relevance of deep earthquakes, an extensive chapter 10 geographically summarizes by subduction zone hundreds of significant deep earthquakes. The chapter also includes deep lunar seismicity, which seems even more mysterious than deep seismicity here on Earth.

For the general audience, the book provides thoughtful descriptions and explanations of the phenomena, including earthquake numbers and sizes, rupture processes, subduction zone structure, and effects of ambient conditions—mainly pressure and temperature—on possible physical processes. Although the book contains no problem sets and is not a textbook, it could be quite useful for a graduate-level topical seminar because of its overview of numerous processes and its synthesis of relevant concepts. For the specialist, the comprehensive literature review and geographic summary are particularly valuable.

Overall, *Deep Earthquakes* is quite an accomplishment. Bottom line: If, like many geophysicists, you are curious about this mysterious phenomenon, check out Frohlich's book. It will most likely answer some questions and raise many others.

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I Am a Strange Loop

Douglas Hofstadter
Basic Books, New York, 2007.
$26.95 (412 pp.).
ISBN 978-0-465-03078-1

Douglas Hofstadter, the son of physics Nobel laureate Robert Hofstadter and once a solid-state physicist himself, became instantly famous with his first book *Gödel, Escher, Bach: An Eternal Golden Braid* (Basic Books, 1979). In it, Hofstadter, now a professor of cognitive science and computer science at Indiana University, Bloomington, exhibits a veritable obsession with the theme of self-reference. That obsession culminated in his fascination with the notion of a "strange loop," a concept he found as a unifying theme in the work of his three protagonists: mathematician Kurt Gödel, artist Maurits C. Escher, and composer Johann Sebastian Bach. Beyond the originality of its theme, *Gödel, Escher, Bach* has become a classic of popular science because of Hofstadter's inimitable personal style: He explains difficult ideas with a mix of dialogue, autobiography, jokes, asides, and endless analogies and metaphors.

In *I Am a Strange Loop*, the dialogues have largely disappeared, but the book is still vintage Hofstadter. The fundamental message, already implicit but mostly overlooked in his 1979 book, according to Hofstadter, is the following: First, the notion of "I," and the associated phenomena of consciousness, thinking, and the soul that Hofstadter broadly identifies, arises because of a "strange loop" inside the brain. Second, that notion turns out to be an illusion, somewhat comparable to the marble one imagines feeling between a large stack of envelopes pressed together.

By definition, a strange loop is a "level-crossing feedback loop" (page 102). What that description means is best illustrated by the example that has motivated Hofstadter since his teenage years. A large part of known mathematics, particularly number theory, can be formalized using the logical system (*PM*) of the *Principia Mathematica*, published from 1910 to 1913 by Bertrand Russell and Alfred North Whitehead. Now, the crux is that number theory by itself is sufficiently rich to encode logical reasoning, as was famously shown by Gödel in 1931. The reinterpretation of certain number-theoretic statements as logical propositions is the level-crossing called for in the definition of a strange loop. In particular, *PM* can be encoded within number theory, so that *PM* is able to reflect on itself. That concept is the feedback in the strange loop at hand.

In the strange loop of the brain that gives rise to consciousness, the role of the lowest level, analogous to *PM* in the mathematical example, is played by the microstructure of the brain, whereas the highest level, which would be comparable to Gödel's reinterpretation mentioned above, consists of the internal symbols representing coarse-