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Physics in Perspective

# Book Reviews

David A. Weintraub, *How Old Is the Universe?* Princeton: Princeton University Press, 2011, 370 pages. $29.95 (cloth).

If all you want is the answer to the question posed by this book, you need read no further than the Introduction. There the author tells you the answers obtained from five methods: (1) the oldest meteorites in the solar system; (2) the oldest white dwarfs in the Milky Way; (3) the oldest globular clusters in the Milky Way; (4) the time, according to Cepheid variables, for the universe to expand to its present size; and (5) the cosmic microwave background (CMB) combined with information about dark matter and dark energy and the universe's expansion. By answering this question at the outset, Weintraub assures you that "the book you are holding in your hands is not a mystery." (p. 2) "But," he continues, "it is *about* a mystery."

If you want to learn how the mystery of the age of the universe has been solved by the five methods listed in the Introduction, you'll want to read the rest of the book. The first method is discussed in the first part, "The Age of Objects in Our Solar System," the next two in the second part, "The Ages of the Oldest Stars," and the last two in the concluding part, "The Age of the Universe." Along the way you will be carried through a historical chronology of how human understanding of the cosmos has evolved, beginning with efforts to calculate the age of the universe from ancient sources not only by James Ussher but also notable scientists like Johannes Kepler and Isaac Newton.

It was not until the discovery of stellar parallax in the nineteenth century that we started to learn how far we were from the nearest stars. About the same time, the spectra of light from stars enabled us to determine their surface temperature and composition. Weintraub repeatedly emphasizes the importance of the Hertzsprung–Russell diagram as "the single most important tool for twentieth-century astronomy." Subsequently Cepheid variables enabled us to measure distances to objects too far away to be measured by parallax, and this was used extensively and reliably once it became clear that there are two types of these variables. This enabled us to realize that nebulae once believed to lie within our Milky Way were actually other galaxies much farther away, and Edwin Hubble observed that most of these galaxies are moving away from us. This expansion, in fact—the notion that an expanding universe could have expanded to its present size from a single point—Weintraub notes, gave rise to the idea of an age of the universe, hence the reason for his book.

Weintraub has prepared this journey through the ways we have understood the age of our universe for the most part with a great deal of care, especially in his explanation of the power spectrum that is used to interpret the CMB. He concludes with a summary that essentially repeats his Introduction, and he has assembled an exquisite set of black-and-white photographs, graphs, and drawings to embellish his text and enhance our understanding. Particularly noteworthy are pie charts comparing the constituents of the universe today and when the CMB was initially emitted. (p. 358) But there are two things that mar this otherwise delightful book: an unusually large number of typographical errors that lead to some incorrect statements; and the absence of endnotes (although some references are cited within the text). Curiously, another book resulting from the same author–publisher partnership *does* contain such endnotes. I can supply an errata sheet listing all the errors I found but not a complete list of the classics in astronomical history that were used to write this book.

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Ray Jayawardhana, *Strange New Worlds: The Search for Alien Planets and Life Beyond Our Solar System*. Princeton: Princeton University Press, 2011, 255 pages. $24.95 (cloth).

Planetary scientist Ray Jayawardhana has written a very readable and exciting overview of the search for life elsewhere in the universe. Having been part of the team that, in 2008, imaged the first exoplanet orbiting a normal star, as well as a journalist at *The Economist* and *Science*, he is well equipped to do so. He sets the stage for his sweeping survey with a lovely epigram that precedes the first of the book's nine chapters. Written by a 10th-century Sung Dynasty scholar, it shows that the ardent belief—one might even say intense longing—that we on Earth are not alone is not limited to Western sensibilities or to the modern era. Teng Mu wrote: "Empty space is like a kingdom, and earth and sky are no more than a single individual person in that kingdom. Upon one tree are many fruits, and in one kingdom there are many people. How unreasonable it would be to suppose that, besides the earth and the sky that we can see, there are no other skies and no other earths."

Once Galileo turned his telescope to the sky in 1609, demonstrating that "the Earth is but one world among many," the possibility that life existed elsewhere became more than a matter of speculation. Human beings could aspire to detect it themselves.

Jayawardhana does a fine job of explaining the various scientific instruments and techniques that have made it possible for us to deepen our understanding of stellar and planetary formation, giving the lie to the conviction of nineteenth-century philosopher Auguste Comte that knowledge of the features of stars and whatever unseen planets might orbit them would be "forever denied to us." Among the several instruments he describes are telescopes on Earth, including the Atacama Large Millimeter Array in northern Chile, which might be able to identify Earths orbiting brown dwarfs and planemos (or planetary mass objects); the airborne observatory SOFIA, which might be able to characterize exoplanets; and a variety of space telescopes, some of which have already made contributions to the field of planetary science, such as the Hubble, Spitzer, and Herschel, as well as the Kepler satellite observatory (launched in 2009), and some that are likely to revolutionize the field in the future, such as the James Webb space telescope (probably not to be launched until 2018, given NASA's budget: http://www.spacenews.com/civil/110412-jwst-launch-2018.html), and two postponed missions, NASA's Terrestrial Planet Finder and the European Space Agency's Darwin mission.

Among the techniques used to detect planets that Jayawardhana describes are the Doppler technique, which uses "spectral lines to trace the subtle dance of stars as planets tug on them"; the gravitational microlensing technique, where a planet's gravitational field can contribute to the lensing effect; and the transit technique, where a planet crossing in front of its parent star's disk causes a small but detectable drop in the visual brightness of the star. (The morning after I drafted this review, an article appeared on the front page of *The New York Times* describing the discovery by two international teams of astronomers, both employing the gravitational microlensing technique, of billions of Jupiter-mass planets for each of the 200 billion stars in the Milky Way galaxy.)

More than on instruments or techniques, however, Jayawardhana focuses on the people who invented them and make use of them. In doing so, he makes it very clear, even without calling specific attention to the fact, that the field of planetary science today includes many senior women scientists and at least some highly productive amateur astronomers. Having recently read and reviewed a history of quantum physics over the last 110 years, in which barely a nod was directed toward women in the field, it was heartening to read the names of so many women in Jayawardhana's coverage that I stopped about halfway through the book jotting down the names of each one mentioned. Also, without announcing that "Amateurs Can Make Important Contributions Too," Jayawardhana succeeds in making the point by covering the work of New Zealander Jennie McCormick, who, despite having dropped out of school at 16, successfully exploited a microlensing event visible from Auckland in the direction of the Milky Way's bulge, enabling her to get the data that confirmed the existence of an exoplanet orbiting the lensing star some 15,000 light-years from Earth. I regret, however, that Jayawardhana slightly patronizes McCormick by his choice of verb in quoting her proud statement when she was included (along with another Kiwi amateur, Grant Christie), as coauthor with Ohio State's Andrew Gould on the *Astrophysical Journal* paper announcing the discovery in May 2005: "'It just shows that you can be a mother, you can work full-time, and you can still go out there and find planets,' *gushed* [italics mine] a proud McCormick."

Among the many scientists named in the book, I was happy to find a fine representation of people who worked in previous centuries, whose contributions set the stage for work being done today. Although physicists tend to associate Albert Michelson primarily, if not exclusively, with the 1887 Michelson–Morley experiment that convincingly challenged the theory of the luminiferous ether, how many know that he was a pioneer in the field of optical interferometry, which is today used to image Earth-size planets? Michelson understood that a telescope's ability to distinguish two stars that seem to be very near one another depended on the size of its mirror, but realized that combining light from two smaller mirrors could do away with the need for building a larger mirror. His interferometer on Mount Wilson, which enabled Michelson to become the first to directly measure the diameter of a star other than the Sun, was thus the forerunner of the VLA, whose 27 antennas in the New Mexico desert function as a single instrument. Similarly, Jayawardhana credits Otto Struve not only with predicting in 1952 that "hypothetical stellar planets" might exist "much closer to their parent stars than is the case in the solar system" but also with describing two methods of exoplanet detection—radial-velocity measurements and stellar transits—that have turned out to be very fruitful. In Jayawardhana's discussion of adaptive optics, he credits Horace Babcock with introducing the idea in 1953 that the effects of atmospheric turbulence in astronomical telescopes might be overcome by placing thin deformable mirrors in the light path, along with tiny motors—actuators—to flex the mirrors to compensate for the effects of turbulent air. In describing how "extreme adaptive optics" instruments in Chile that should be operational by 2012 will make use of tricks "to achieve the high contrast needed to detect dim planets next to bright stars," Jayawardhana includes the coronagraph as central to one of those tricks, and then goes on to credit the invention to French astronomer Bernard Lyot in 1930. Even in his historical coverage, Jayawardhana includes women who made scientific contributions at a time when their presence in the field was rare. For example, he credits Margaret Lindsay Huggins (1848–1915) with carrying out investigations, along with her husband, William Huggins, that "marked the birth of modern astrophysics, shifting the focus away from charting positions, shapes, and apparent motions of celestial objects to understanding their physical nature." (This point may explain why Lady Huggins's papers are held at Wellesley College, a woman's undergraduate institution, where her good friend Sarah Whiting was director of the Wellesley College Observatory.)

If I have an overall complaint about this book, however, it is that the narrative is studded with too many names. While it's nice to pay tribute to individuals and their work, it's a bit daunting to keep track of who did what when, even for someone who recognizes virtually all the names and knows many of the individuals cited. If I may refer once again to *The Quantum Story*, the history of quantum science to which I referred above, what made that book so engaging was the human interest stories the author, Jim Baggott, tells about the contributors to the theory's development over more than a century. Jayawardhana tells only a few such stories, but they are among the things that I am most likely to remember from his book. Who wouldn't be amused, for example, to learn that Frank Shu, "one of the world's foremost experts on star formation," whose "theoretical work over the past three decades is at the heart of our current understanding of the birth process of stars," is particularly proficient in the first-grade curriculum, having covered it three times as a result of his family's moves from mainland China to Taiwan and then to the United States? In a few cases, including his own, Jayawardhana personalizes the scientists whose work he is discussing by describing formative childhood experiences. I was charmed to learn that Jayawardhana traces his career interests back to a nighttime walk with his father in the garden of his childhood home in Sri Lanka. When the boy heard from his father that people had walked on the Moon, "I was astonished: the idea that one could walk on something in the sky boggled my mind.... Looking back, that moment has had a defining impact on the path I have taken in life." I also found endearing Jayawardhana's description of the young Heather Knutson, whose expertise in exoplanet heat distribution I am the more likely to remember as a result of the picture he paints of her as a child, venturing out to the edge of the southernmost and largest of the Marshall Islands, Kwajalein, where her parents worked on the U.S. Army missile range, "armed with a red flashlight and a book of constellations."

Because Jayawardhana is overly generous in naming so many individuals, I found one omission all the more glaring. In his coverage of the 1977 discovery of the rings of Uranus, which involved a stellar occultation—a variation on the transit method—Jayawardhana attributes the achievement only to three anonymous astronomers aboard the Kuiper Airborne Observatory. Given the prominence of James Elliot in the field of planetary science (his recent demise, on March 3, 2011, occasioned obituaries in *The New York Times* and elsewhere that hailed this and others of Elliot's scientific contributions), I find it at least regrettable, if not unforgivable, that Jayawardhana omits his name and those of his colleagues, Edward Dunham and Douglas Mink.

My only other significant issue with the author is based on a paragraph in Chapter 5 in which he links a boyhood memory of his—"I saw a transit of Mercury as a fifteen-year-old in Sri Lanka"—with a dismissal of the scientific value of observations of transits of Mercury and Venus today by "most professional astronomers." While it is true that the 18th-century scientific goal of observing transits to determine the distances in the solar system has been superseded by other methods, some professional scientists hope to exploit the rare opportunity of the upcoming June 2012 transit of Venus to make a variety of observations with high-precision instruments. In addition to measuring the effect of the transit on the Total Solar Irradiance, these scientists hope to learn more about the structure of the atmosphere of Venus. Additionally, what is learned from the forthcoming transit will help astronomers improve observing methods and strategies to better understand the similar transits of extrasolar planets, which, as Jayawardhana himself claims, "are at the forefront of astrophysics." Furthermore, the sharp silhouettes of Mercury and Venus during transits are also useful for calibrating the instrumental resolution of spacecraft telescopes.

These reservations notwithstanding, I recommend this book for its interesting and extensive coverage of a fascinating field. As Jayawardhana notes, if astronomers succeed in finding definitive signs of life elsewhere in the Universe, "the ramifications for all areas of human thought and endeavor—from religion and philosophy to art and biology—are profound, if not revolutionary." Given the truth of that statement, it is hard to believe that members of the successful team would be denied a Nobel Prize in Physics on the grounds that the work relies on no "new physics," a possibility that Jayawardhana raises in Chapter 4. (There is no Nobel Prize in Astronomy.) Surely the revolution in science such a discovery would mark—"perhaps only rivaled by Copernicus's heliocentric theory that dislodged the Earth from the center of the universe or Darwin's discovery of evolution that suggested all species on our planet, including humans, descended from common ancestors"—should be recognized by the conferring of this most prestigious of all scientific awards.

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Toby E. Huff, *Intellectual Curiosity and the Scientific Revolution: A Global Perspective*. Cambridge: Cambridge University Press, 2011, xiii + 354 pages. $27.99 (paper).

The stated goal of Toby Huff's *Intellectual Curiosity and the Scientific Revolution: A Global Perspective* is to answer the question of why the Scientific Revolution of the 16th and 17th centuries occurred in Europe and not in other cultures, which were at the time at least equally advanced. "Given this extraordinary pattern of discovery, it is easy to ask why all this did not happen elsewhere. Simply put, why the West? Why did the Western world take off and become the dominant scientific, economic, and political power on this planet? Why did the great civilizations of China, India, and the Muslim Middle East, with their long records of growth and accomplishment fall behind." (p. 3) As discussed below, one might very well question the value of these queries, but certainly the answers provided by Huff are disappointing. The book, however, is not without redeeming value. It provides a useful, if flawed, account of the scientific achievements of that period.

Huff correctly reminds us that the Scientific Revolution occurred not only in astronomy and physics, but also in other areas of science. He points out that Vesalius's *The Fabric of the Human Body*, a major corrective to, and change from the received view of Galen on the human body, was published in 1543, the same year as the publication of Copernicus's *On the Revolution of the Heavenly Spheres.* The early 17th century also marked the discovery of the circulation of the blood by William Harvey as well as the pioneering work in microscopy by Leeuwenhoek and others that began the study of microbiology. Huff provides an interesting story concerning the use, and importance, of reliable witnessing in the establishment of scientific results in that period, a method of validation that appears several times during this period. Leeuwenhoek's observations of "little animals" in a drop of water were reported to the Royal Society, and Nathaniel Grew, an English microscopist, was asked if he could replicate Leewuwenhoek's observations. He couldn't, which cast doubt on Leeuwenhoek's results. Leeuwenhoek responded by repeating his observations in the presence of reliable witnesses, and included testimonials from two ministers, one public notary, and "others of good credit to the number of eight." (p. 203) The little animals were also later observed by Robert Hooke, the author of *Micrographia*, an important contribution to microscopy also discussed by Huff. They were also seen by several other reliable observers including Sir Christopher Wren, which removed any doubt concerning Leeuwenhoek's "little animals."

Huff devotes an interesting chapter to "Weighing the Air and Atmospheric Pressure." This includes the work of Torricelli on the barometer and the experiments showing the variation of atmospheric pressure with altitude by Blaise Pascal on the Puy de Dôme.* Huff notes that Pascal knew of the work of Albert of Saxony and Jean Buridan in the 14th century that argued for the impossibility of a vacuum and did experimental work on the question. Buridan, for example, states, "But let us show by experience that we cannot separate one body from another unless another body intervenes. Thus if all the holes in a bellows were perfectly stopped up so that no air could enter, we could never separate their surfaces. Not even twenty horses could do it if ten were to pull on one side and ten on the other; they would never separate the surfaces of the bellows…."** This was the experiment later performed by the mayor of Magdeburg and the inventor

* Cycling enthusiasts will recognize this as also the location of one of the great *mano-a-mano* contests in the history of cycling, the climb up the Puy de Dôme by Jacques Anquetil and Raymond Poulidor in the 1964 Tour de France.

** Jean Buridan, "Experiments Demonstrating that Nature Abhors a Vacuum," in Edward Grant, ed., *A Source Book in Medieval Science* (Cambridge, Mass.: Harvard University Press, 1974), pp. 326-327.

of the air pump, Otto von Guericke. Rather than showing the impossibility of a vacuum, as Buridan and Albert of Saxony believed, these experiments actually demonstrated the pressure of air. Huff argues quite plausibly that these and later experiments led to the steam engine.

The early 17th century also featured work on electricity and magnetism, most notably the work of William Gilbert on magnetism. Huff remarks that Gilbert was influenced by the 13th-century scholar, Petrus Peregrinus, who had found that magnets had two poles, that like poles repel whereas unlike poles attract, and that the Earth itself was a magnet. Kepler, in fact, used magnetic forces to provide the motive power for planets in their orbits. This was a major change toward a mechanical view of nature because Kepler changed the cause of a planet's motion from an *anima motrix*, a spirit moving the planet, to a force moving the planet, a *vis motrix*. Huff notes that Gilbert also worked on electricity, creating a "versorium," a type of electroscope. He also describes other work on electricity done by Hauksbee, Gray, and von Guericke.

Huff's summaries of work on other aspects of the Scientific Revolution are brief and useful, but I found his discussion of the more central work of Copernicus, Kepler, Galileo, and Newton sketchy and far from satisfactory. The lack of detail on Galileo is surprising because Huff is quite enamored of the telescope, which he describes as a "discovery machine." Although Galileo's telescopic discoveries such as the moons of Jupiter, the phases of Venus, and the mountains on the moon, did provide support for the Copernican system, Huff fails to emphasize that the revolutionary work of Copernicus and Kepler was based on naked-eye observations, in the case of Kepler on those of Brahe, Huff does provide us with an interesting chapter on the introduction of the telescope in China and the failure to use it for astronomical purposes. He does not, however, provide us with any explanation of how a telescope works. I found his figures confusing rather than explanatory. A short technical appendix, perhaps even using the lens or mirror formulas, would have been helpful.

There seems to be an air of triumphalism in Huff's account. There are three chapters with "Infectious Curiosity" in their title that describe scientific achievements in Europe. It is as if Huff doesn't believe that such curiosity was present in other cultures. He seems to regard science in Europe as obviously superior to that produced in those other cultures. This is demonstrated in Huff's discussion of the Chinese reaction to the introduction of the telescope. He seems surprised that they didn't recognize the importance of the instrument and use it for the same purposes as did European scientists. Huff's Eurocentric view also appears elsewhere. Although, as noted above, Huff discusses important work done by European scholars during the later Middle Ages, he does not, I believe, adequately recognize the contribution of work done in the Middle East. Scholars such as Alhazen, Avicenna, Averroes, and al-Kindi, to mention only a few and to use their Latinized names, not only preserved Greek science, but made important additions to it. In addition, the work of translators who made this work available to Europe is mentioned in a single sentence. Gerard of Cremona, who made translations of the works of both Aristotle and those other scholars, is never mentioned.* The astronomical work done in the Middle East up to the 16th century is dismissed because it was geocentric, even though it involved interesting calculational methods.

To be fair, Huff may have discussed these contributions in an earlier book, *The Rise of Early Modern Science: Islam, China, and the West*.** That account has been criticized rather severely by George Saliba, an expert on astronomy in the Middle East during the Middle Ages.*** Some of

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* It seems fair to say that Gerard made it possible for European science to enter the 12th century.

** Toby Huff, *The Rise of Early Modern Science: Islam, China, and the West* (Cambridge: Cambridge University Press, 1993).

*** George Saliba, "Seeking the Origins of Modern Science?" *Bulletin of the Royal Institute for Inter-Faith Studies* **1** (1999), 139-152; also available at the website http://baheyeldin.com/history/george-saliba-1.html.

Saliba's criticism applies to the current book. Saliba asks, "More particularly, one should ask whether it makes sense to speak of science, whether modern or not, in such cultural, linguistic, or national terms, when the very processes of science themselves respect no such boundaries and pay no heed to such sentiments."* In work on the history of contemporary science we rarely use such terms. One does not speak of the revolutionary work on special relativity or on quantum mechanics as German or European science, but rather as science.

Huff offers a rather simplistic account of the reasons why the Scientific Revolution occurred in Europe rather than elsewhere. "At the heart of this development was the jurisprudential idea of a corporation, a collection of individuals who were recognized as a singular 'whole body' and granted legitimate legal autonomy."** This helped to establish universities as autonomous institutions, which Huff believes provided the institutional and intellectual foundation for modern science. One might question whether this is the most important necessary condition for that result. It is certainly not sufficient. Although Galileo and Newton were faculty members at a university, neither Kepler, Copernicus, nor Brahe held such positions. In addition, Huff provides no real arguments in support of his view. It is, rather, often just asserted. Saliba suggests, on the other hand, that the enormous wealth that accrued to Europe because of the colonization of the New World provided the economic support for the scientific work. Certainly Brahe, Kepler, and Galileo benefited from patronage. These issues deserve far more discussion than they received in Huff's book.

Although Huff doesn't reach his goal of explaining why the Scientific Revolution occurred in Europe and not elsewhere, he does make a case that there was such a revolution and that it took place in more than just physics and astronomy. It is a useful reference for such material.

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* Saliba, *ibid*., website, p. 3.

** Toby Huff, "Reply to George Saliba," website http://baheyeldin.com/history/toby-huff-1.html, p. 4.