books

An advocate for the anthropic principle

The Cosmic Landscape: String Theory and the Illusion of Intelligent Design

Leonard Susskind
Little, Brown and Co, New York, 2006. $24.95 (403 pp.). ISBN 0-316-15579-9

Reviewed by Paul Langacker

The Great Debate in 1920 at the Smithsonian Museum of Natural History between Harlow Shapley and Heber Curtis concerned the size of the Milky Way and whether it constituted the entire universe or was just one of innumerable island universes, or separate galaxies. The issue was settled in 1924 when Edwin Hubble observed Cepheid variables in the Andromeda galaxy, which allowed him to show that Andromeda was an enormously distant, separate galaxy. And like Shapley's determination that the solar system is not at the center of our galaxy, and the earlier Copernican revolution, Hubble's findings helped to demote the significance of humans. Hubble summarized it quite well: "The history of astronomy is a history of receding horizons."

Recently, a new but related great debate has been quietly raging within the communities of string theorists and cosmologists. One side holds the traditional view that the laws of physics and the values of the physical constants are the same throughout the universe—a universe presumably determined as the unique solution of some ultimate physical theory. Another side, a growing minority in both communities, suspects the existence of an enormous landscape of some 10^{500} possible vacua of an underlying superstring theory. Each vacuum leads to its own laws of physics, and no known principle distinguishes one as preferred over the others. Furthermore, most of those who hold that minority view speculate that the universe consists of an infinite multiverse, or megaverse, of regions, each expanding or contracting according to its own laws of physics. New regions are constantly formed by quantum tunneling so that all of the vacua of the landscape are sampled.

Leonard Susskind's *The Cosmic Landscape: String Theory and the Illusion of Intelligent Design* surveys the new debate clearly and amusingly for the general reader. Susskind, one of the inventors of string theory and a leading advocate of the landscape and multiverse ideas, does an excellent job developing the necessary background in quantum mechanics, relativity, particle physics, supersymmetry, string theory, black holes, cosmology, and inflation.

Underlying the debate between the landscape idea and the more traditional view is the observation that our universe and its physical principles appear to be remarkably fine-tuned to allow the development of life: the anthropic principle. For example, small variations in the relative masses of the electron and proton or in the value of the fine-structure constant would preclude the necessarily rich structure of atoms and molecules. Similarly, the observed vacuum energy, or cosmological constant, is some 120 orders of magnitude smaller than what is typically expected from string theory. Steven Weinberg has argued that a positive value much larger than observed would have led to such rapid expansion of the universe that galaxies and stars could never have formed; a large, negative value, on the other hand, would have led to a catastrophically rapid collapse. Many other examples exist in Big Bang nucleosynthesis, long-lived stars, and the supernova explosions needed to eject elements into the universe. Susskind describes at great length "The Mother of All Physics Problems"—the cosmological constant—and the other lucky accidents that make our existence possible. He argues strongly that the only plausible nonsupernatural explanation is "a Landscape of possibilities populated by a megaverse of actualities."

Except for possibly appealing to the idea of an intelligent designer, the traditional view of unique laws and constants offers little explanation for why we are fortunate that nature has just the right conditions for life. The multiverse–landscape paradigm, on the other hand, provides a plausible framework for the anthropic principle: Life only evolved in the tiny fraction of regions of the multiverse that had suitable conditions. This view is analogous to the paradigm shift that resolved the old question of why we are so lucky that Earth has hospitable conditions: If billions of stars in the galaxy have planets, then some are bound to be just right.

Many scientists are strongly opposed to the multiverse–landscape paradigm. Some objections are technical. For example, are there really 10^{500} vacua, or does the multiverse really exist? Others are that the ideas are not testable and not really science, or that they might seduce researchers into giving up the traditional goal of finding a unique and elegant explanation for the observed laws of nature. Susskind makes no attempt to give an impartial overview—after all, he is advocating his own ideas. However, he does offer a reasonable survey of the objections and his own responses to them.

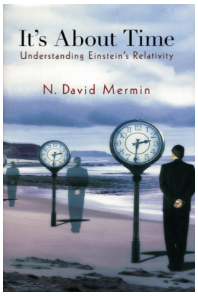
The Cosmic Landscape is a fascinating introduction to the new great debate, which will most likely be argued with passion in the years to come and may once again greatly alter our perception of the universe and humanity's place in it.

Paul Langacker is a professor in the department of physics and astronomy at the University of Pennsylvania in Philadelphia. His research is in theoretical particle physics, and he is especially interested in making connections between fundamental theory, experiment, and astrophysics.

It's About Time: Understanding Einstein's Relativity

N. David Mermin
Princeton U. Press, Princeton, NJ, 2005. $29.95 (192 pp.). ISBN 0-691-12201-6

I first came across relativity theory in an example featured in an instruction book for an early electronic calculator. I was 11 years old and was amazed to read that an astronaut could travel for 50 years



(as measured on Earth) near the speed of light and return to Earth with his clocks showing that only 25 years had elapsed since his journey began. I wanted to know more—and I wish I'd had David Mermin's new book then!

It's About Time: Understanding Einstein's Relativity is based on Mermin's lectures to non-science majors at Cornell University, which the author has been giving intermittently for the past 30 years. This is his second book on relativity theory, the first being *Space and Time in Special Relativity* (McGraw-Hill, 1968). Both books share the goal of introducing special relativity to nonexperts; in broad terms, both cover similar topics. But since his first book, Mermin's ideas about how relativity should be taught have developed considerably. Given the lectures on which the new book is based, it's no surprise that *It's About Time* contains only simple algebra; yet there's nothing superficial about the level of understanding that it aims to impart.

The book begins with an unusually clear discussion of the principle of relativity in Newtonian mechanics. The reader needs very little prior knowledge. For example, in chapter 1, Newton's first law is stated, and Mermin spells out the distinction between speed and velocity. Reference frames are introduced and used to predict what will happen in simple collisions. The way in which velocities transform between frames is considered carefully, so that when the constancy of the speed of light appears for the first time in chapter 3, its strangeness is immediately apparent. Later chapters cover the relativistic velocity-addition law, simultaneity, and measurements of time and distance by different observers. The book ends with an introduction to spacetime diagrams, a derivation of $E=mc^2$ in which the algebra gets a little harder, and a brief look at time in general relativity.

Topics covered are standard for a book of this sort. What makes Mermin's book special, however, is the high quality of exposition at every level. He offers such delightful minor touches as using "Alice" and "Bob" to replace the reference frames S and S'. His use of the foot as the unit of length—redefined so that the speed of light is exactly 1 ft/ns—is amusing, especially when combined with centimeters. The book has plenty of clever and—to me, at least—original arguments that get the important ideas across in a very clear way. For those who wish to teach the subject themselves, one example in particular, which involves two trains with opposite velocities, is well worth copying. What makes the book as a whole so enjoyable to read is the steady pace at which the subject unfolds. The author spends as much time on each idea as he considers necessary instead of treating each in proportion to the number of questions anticipated on an end-of-the-year examination. As a result, the book has excellent sections on reference frames and collisions in nonrelativistic mechanics, and its long introduction to spacetime diagrams is the best I've ever seen. Nowhere is the book too intense, and the learning curve for readers has a fairly constant slope.

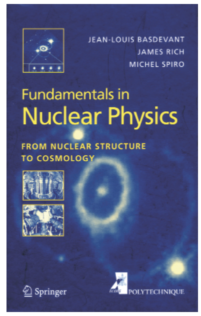
The book contains no four vectors and no Lorentz transformation; it mentions the Michelson–Morley experiment only in passing. Despite its elementary level, I'd recommend *It's About Time* to physicists. They won't learn any new physics, but they can watch Mermin, a master teacher, at work—and instructors will almost certainly include some of the ideas in their own teaching. Although Mermin's book doesn't have enough material to make it suitable as a standalone text for an undergraduate course, any undergraduate can read it with profit, either before or after learning about special relativity.

What about younger people? I teach physics to pupils aged 13 to 18, and I shall certainly be ordering some copies for a few of them to read. The book's high English-to-math ratio means that even some of the 13-year-olds could get something out of it. Those 16 and older should be able to learn a lot from the book, and I'm sure they'd enjoy it. The physics I teach at school rarely involves chains of reasoning with more than two steps. I hope *It's About Time* will show some of my students what real physics is like.

Nigel Dowrick
Benenden School
Kent, UK

Fundamentals in Nuclear Physics: From Nuclear Structure to Cosmology

Jean-Louis Basdevant, James Rich, and Michel Spiro
Springer, New York, 2005. $79.95 (515 pp.). ISBN 0-387-01672-4



The past 30 years have brought significant advances in astrophysics, cosmology, and neutrino physics. Observers using very powerful telescopes can explore element abundances in distant metal-poor stars. Researchers are making increasingly more precise observations of the many elements formed in the early universe, various aspects of the cosmic microwave background radiation, and the accelerated expansion of the universe. Physicists now understand the reasons for the deficiency of solar neutrinos in earlier measurements and have glimpsed the physics beyond the standard model by measuring differences between squares of neutrino masses and two of the neutrino mixing angles. Experimenters are now working to measure the third angle and reduce the uncertainties in what has already been measured.

Nuclear physics plays a crucial role in all of the above developments, a fact perhaps not widely recognized. *Fundamentals in Nuclear Physics: From Nuclear Structure to Cosmology*, by Jean-Louis Basdevant, James Rich, and Michel Spiro, is aimed at those readers who need a working knowledge of nuclear physics to design neutrino- or dark-matter detection experiments and need to analyze their results. Similarly, interpretation of observations of the stellar and primordial element abundances requires an extensive knowledge of nuclear physics.

The authors are well-regarded scientists who work at the interface of nuclear and particle physics and astrophysics, and the book is based on the late-1980s lectures they gave at the École Polytechnique in Paris. The text succeeds quite well in its aims. Not too many books on the subject share the same goals. The venerable *Experimental Nuclear Physics* (Wiley, 1953–59) by Emilio Segrè is out of date: It covers neither modern neutrino physics nor astrophysics. Two widely cited books, *Cauldrons in the Cosmos: Nuclear Astrophysics* (U. of Chicago Press, 1988) by Claus Rolfs and William Rodney and the revised version of *Principles of Stellar Evolution and Nucleosynthesis* (U. of Chicago Press, 1983) by Donald Clayton, originally published in 1968, are mostly focused on nuclear astrophysics and also need to be updated.

In *Fundamentals in Nuclear Physics* the authors have found the right balance between presenting nuclear physics as a domain of fundamental