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Quantum Physics for Poets. Leon M. Lederman and Christopher T. Hill. 338 pp. Prometheus Books, Amherst, NY, 2011. Price: $28.00 (hardcover) ISBN 978-1-61614-233-9. (Marcia Bartusiak, Reviewer.)

We've all witnessed it: students who are obliged to fulfill a science requirement flocking to biology or geology classes and tip-toeing away from physics. Some claim math phobia, others are bored by the thought of those ubiquitous boxes sliding down inclined planes. Yet, paradoxically, many from this same audience eagerly seek out the latest books on theoretical physics, resulting in such works as Brian Greene's *The Elegant Universe* and Stephen Hawking's *A Brief History of Time* setting records on the best-seller lists.

Let's face it—modern physics is both fun and enthralling, with its particle/wave duality, spooky action-at-a-distance, quantum tunneling, and superstrings. Like barkers at a carnival, such phenomena are a surefire way to draw people into the physics tent. After previously teaming up to write their well-received *Symmetry and the Beautiful Universe*, which demonstrated how symmetry is a vital mathematical component throughout the laws of physics, Nobel laureate Leon Lederman and his Fermi National Laboratory colleague Christopher Hill continue their journey in popularization with this more straightforward, introductory review of the basic concepts of quantum physics.

Their reason for doing so, they write, is simple: "What scientists say about the world should be a part of everyone's education. And quantum theory, in particular, is the most seminal change in viewpoint since the early Greeks gave up mythology to initiate the search for rational understanding of the universe." [p. 33]

To set the stage for understanding that startling transformation, the authors first provide a breezy and engaging summary of classical physics, from Galileo and Newton to Faraday and Maxwell. It's all a familiar stew to the physics-trained, but the ingredients are still worth savoring, for they remind us of the titanic shift in perspective that physicists had to undergo when first confronting the quantum world at the start of the 20th century.

One of the first signs of alarm was rooted in the "ultraviolet catastrophe." Or, as Lederman and Hill more wittily explain, "Classical theory predicts that your toaster wires should glow blue…." [p. 91] Under traditional rules, blue light, having smaller wavelengths, should be emitted more copiously when matter is heated. But a toaster's coils glow red because Max Planck (and later Einstein) ingeniously decided that light comes in lumps and the energy of each packet—that is, quantum—is directly linked to its frequency. A toaster simply doesn't have enough *oomph* to emit many high-frequency, high-energy blue photons. Here, the authors compare the effect to an audience crowding into an auditorium to hear a pianist (an analogy I'm tempted to steal); front-row seats are made so expensive that most concert-goers end up in the middle of the hall, close enough to see but easier on their budget.

Planck's revision in 1900 seemed innocent enough, but from then on the weirdness mounted as the century progressed. From there, the authors swiftly introduce us to the photoelectric effect, double-slit experiments, Compton scattering, and Ernest Rutherford proving that an atom is mostly empty space. When doctoral student Louis-Victor de Broglie suggested in 1924 that elementary particles could also act like waves, his thesis examiners were so flummoxed they checked with Einstein to make sure it could be true. It was, earning de Broglie a Nobel prize.

Lederman and Hill promise just a "tad bit" of math in their presentation [p. 33], but they can't seem to help sneaking some in when explaining certain concepts, such as the Heisenberg uncertainty principle. They introduce non-commutative mathematical systems and then note that "the heart of *non-commutativity* of x and p is that, for a particle, both the position…and the momentum…*cannot be measured to have definite values simultaneously*." This essential connection is likely to remain as cryptic to a newcomer as de Broglie's matter waves were to his professors. For explaining uncertainty to laypersons, I prefer the observation-based approach used by Robert March in his classic book *Physics for Poets.*

The authors are more successful in showing how quantum theory, via Max Born (who, by the way, we learn was singer Olivia Newton-John's grandfather!), overturned the Newtonian world of absolute certainties and transformed nature into a game of probabilities, which "represented a scientific and philosophical upheaval that was nothing less than an intellectual Armageddon." [p. 141] Einstein, for one, was sure that classical determinism would re-emerge at some deeper layer. And, in a challenging yet valuable chapter, Lederman and Hill demonstrate how a quiet-spoken Irish theorist named John Bell set up a test, an inequality that proved Einstein was wrong.

Quantum Physics for Poets also provides many fascinating examples of how quantum physics has woven itself into our everyday world, from modern chemistry to molecular biology. "God may play dice with the universe," the authors write, "but man has managed to control the quantum domain enough to fashion the transistor, tunnel diodes, dye lasers, x-ray machines, synchrotron light sources, radioactive tracers, scanning tunneling microscopes, superconducting magnets, positron emission tomography, superfluid liquids, nuclear reactors and nuclear bombs, MRI machines, the microchip, and the laser—to name a few." (p. 151) If we can at last control entangled quantum states, they continue, we'll be able to build a quantum computer that "could solve in a year a problem that would take today's best computer several billion years!" (p. 284)

By now, the reader may be impatient for my ultimate prognosis: Is this book truly for poets? Certainly for the physics-minded bard, who is eager and willing to learn about wave functions, wave interference, fractional spin, negative energy, hidden variables, fermions, and bosons. That's a good reason to keep it on the bookshelf for my science-writing: it offers a concise and handy primer, when I need one, on the history, ideas, and current applications of quantum physics.

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The 4% Universe: Dark Matter, Dark Energy and the Race to Discover the Rest of Reality. Richard Panek. 320 pp. Houghton Mifflin Harcourt, Boston, 2011. Price: $26.00 (paper) ISBN 978-061-8982-44-8. (Ira Wasserman, Reviewer.)

Cosmologists have now concluded that only about 4%–5% of the mass–energy density of the Universe is in the form of "ordinary matter"—atoms, molecules, ions, electrons. Of the remaining 95%–96%, only about 24% is matter, and that is presumably made of some new elementary particle that we hope will be discovered soon, either by "cosmic ray" experiments passively seeking weak signatures of their interaction with ordinary matter, or by direct production at the Large Hadron Collider. The rest is dark energy, which pervades the cosmos but may be inert except for accelerating the expansion of the Universe.

Richard Panek's book traces the history of how astronomers and physicists were led to this unexpected picture of the composition of the Universe. While his book is not really about the science behind these developments, it is a fast-paced investigation of how cosmology grew from a field largely scorned by serious scientists to its present prominence in the world of physics.

Central to **The 4% Universe** is a clash of cultures. On the one hand, there is the physicists' goal of reducing the Universe to a few simple ideas from which all other consequences flow naturally. On the other hand is the astronomers' vision of the Universe as relentlessly complex, not simply the unavoidable consequence of a few basic equations of physics.

Panek demonstrates this dichotomy via numerous vignettes. One centers on the original discovery of the Cosmic Microwave Background Radiation (CMB) by Penzias and Wilson. The basic outline of this story is well known: where Robert Dicke and his collaborators at Princeton set out to discover the CMB via painstaking experiments, Arno Penzias and Robert Wilson at Bell Labs scooped them serendipitously, but were alerted to the Princeton work, and hence the possible interpretation of their discovery, by Bernard Burke. At the center of this story is the young Jim Peebles, who despite his conviction that the Universe cannot be as simple as a smooth Big Bang model, nevertheless forged ahead to set the agenda for much of modern cosmology, starting with work on nucleosynthesis and recombination in a homogeneous expanding world, but then moving on to elucidate the development of small inhomogeneities.

A second vignette centers around the use of Type Ia supernovae for measuring the history of cosmological expansion. In this case, there were two observational programs, one initiated by physicists at Lawrence Berkeley Laboratory (the Supernova Cosmology Project, ultimately led by Saul Perlmutter) and a second initiated by astronomers (the High-z survey, ultimately led by Brian Schmidt). How these two collaborations approached this problem is illustrated by their methodology for "standardizing" the luminosities of Type Ia supernovae, so that they could be used for determining "luminosity distances" as a function of redshift. Although both employed the supernova light curves—that is, the observed flux as a function of time—the physicists' method relied on a self-similar template with, basically, two parameters, a time scale and related peak luminosity, but the astronomers' method used a more complicated statistical approach that combined light curves at various colors. It is remarkable that the two approaches led to similar conclusions.

These two stories also reveal very different outcomes of scientific competitions. As Panek's book relates, the Princeton group shared their cosmological insights with Penzias and Wilson almost immediately, leading to coordinated publications. Ultimately, Penzias and Wilson won the Nobel Prize for their discovery, which they shared, somewhat improbably, with PyotrKapitza, presumably because of the near coincidence in temperatures of their otherwise unrelated studies. Robert Dicke died as one of the greatest 20th century physicists who never won a Nobel Prize.

The inference of the existence of dark energy from observations of Type Ia supernovae did not follow such a noble, collaborative path. The competition was fierce, and Panek documents the growth of strained relationships between the groups, at whose core appears to be disagreements over priority of discovery. Both collaborations have been amply honored for their work; whether they garner a Nobel Prize remains to be seen.

The 4% Universe is more about the conduct of science than about the physics and astronomy behind the discoveries of dark matter and dark energy. Nevertheless, it does raise some of the important issues for the future of this sort of science, not least of which is the question of when do we simply concede that the dark energy is a cosmological constant with a value that is ridiculously small but not zero. But more importantly, Panek's lively writing about the numerous personalities who pushed cosmology forward emphasizes the human aspect of scientific endeavor rather than presenting discovery as an implacable march to the truth by faceless armies of cosmologists.