BOOKS: COSMOLOGY

A Hawking-eye View of the Universe

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In the world of Newton and Galileo, space and time were the flat, featureless canvas on which were painted the then-known celestial objects. Einstein's canvas was curved and it had bumps and wiggles caused by the presence of matter. During the past few decades, it is the canvas itself that has increasingly become the focus of study, as the dimensionality, shape, and nature of space and time have become intertwined with subatomic particles, black holes, and superstrings in a unified quest by physicists and cosmologists to understand the laws of physics and how the Universe came to be.

The Universe in a Nutshell
by Stephen Hawking
Bantam, New York, 2001. 224 pp. $35, C$53, £20. ISBN 0-553-80202-X.

This enterprise is the subject of Stephen Hawking's *The Universe in a Nutshell*. A theoretical physicist, Hawking first emerged in the 1960s with brilliant work that helped elucidate the mathematical structure of general relativity. His celebrity in physics was solidified by his 1974 discovery of "Hawking radiation," the quantum-mechanical emission of radiation from black holes. This work opened the attack on the merger of general relativity and quantum mechanics, the central focus of theoretical physics today. Since then, Hawking has weaved in and out of the mainstream as both a central figure and sometimes iconoclast in the world of physics. With the spectacular success of *A Brief History of Time*, he has also become science's biggest pop star since Einstein.

Thus, expectations for *Universe* are high. The book does not disappoint. With colorful illustrations besetting self-contained essays rather than a single story, this book discusses new developments in a way that will be even more accessible to a wide audience than his previous book.

Hawking reviews quantum mechanics, general relativity, the big bang, and black holes, and then goes on to tackle string theory, M theory, imaginary time, multiple histories, the information-loss paradox, the black-hole holographic principle, extra dimensions, and time travel, among other things. These topics are certainly as daunting as one might guess. Some are still developing ideas, and some are fairly challenging concepts, even for theoretical physicists (present company included). Hawking does not underestimate his audience; to his credit, he does not water down the physics nor does he filter out the most difficult ideas. Instead, he presents the topics fairly and honestly, though stripped of the mathematical language that physicists usually use.

Not every reader will necessarily understand every concept. Are we all really supposed to grasp what he means by imaginary time or cancellation of infinities in supersymmetry? Or why a black hole's entropy is related to the area of its horizon? Perhaps not. But readers will become familiar with some of the more tantalizing issues theoretical physicists are confronting and may even share the frustration we scientists sometimes face in our continued efforts to sort these all out.

Although much of the subject matter itself is intrinsically difficult to understand, many of the topics in the book are explained with considerable lucidity, sometimes using novel and intriguing approaches. His argument for why quantum gravity should be important to us is interesting; his singularity theorems show that quantum gravity will be required in order to understand the distant past, and possibly the distant future of the Universe. The discussion of large extra spatial dimensions, a popular theme among particle theorists these days, is also very good. And the discussion of imaginary time might actually help many readers understand it.

Perhaps the greatest strength of the book, however, is the abundance of beautifully rendered images of the topics discussed. Although the language of physics is mathematics, the subject is not. The most powerful ideas in physics are motivated first by a strong physical image, not mathematics. In fact, years before he was able to understand the mathematics to describe it, Einstein developed an intuitive picture of how mass should warp spacetime. Many of the book's pictures, thus, go a long way toward clarifying the notions Hawking discusses. A picture of the digestive tract of a camel, for example, shows very clearly why life cannot arise in two spatial dimensions; a simple but elegant picture illustrates why the night sky in a static and infinite Universe would be bright. More than the dry diagrams to which physicists may be accustomed, these vibrant pictures will resonate with the popular imagination. The Escher-like imagery is suggestive of the paradoxes that often lead to breakthroughs in physics.

Creative ideas are certainly required for progress in science, but success is ultimately achieved at the point where imagination and reality intersect. By offering opinions (his own and others) as well as historical anecdotes, Hawking defines the boundaries among the well-established, the speculative but plausible, and the far-fetched. Though I doubt that all of these heavy concepts will ultimately wind up in the true theory of everything, I would not be surprised to find at least some of them there. The book is fascinating not only as a depiction of the inspiration of pursuit, but also as a description of ingredients that may eventually become truth.

Curved spacetime. Time has shape but only travels in one direction (the locomotive).

Hawking's spirited discussion is filled throughout with ambition, big ideas, plain talk, and humor. The excitement of exploration and discovery is evoked in every chapter, even if the explanations aren't crystal clear in every case. Although readers may not attain Hawking's depth of understanding, they will surely be infected by his curiosity.

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