Book Review

The Book of Nothing:
Vacuums, Voids, and the Latest Ideas About the Origins of the Universe

Reviewed by Jean-Pierre Luminet

The Book of Nothing: Vacuums, Voids, and the Latest Ideas About the Origins of the Universe
John D. Barrow
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According to the Greek poet Hesiod (eighth century B.C.), the world was created *ex vacuo*, i.e., out of the void that existed before it, rather than *ex nihilo*, out of nothing. The distinction is fundamental and has led to centuries of commentaries and controversies in the fields of philosophy and religion as well as science.

Indeed, a *Book of Nothing* was already published in 1510 in Amiens, France (with the Latin title *Liber de Nichilo*). Its author, the illuminist philosopher Charles de Bouelles, invoked the metaphysical and mystical doctrines of Nicolas of Cusa and the Neo-Platonists to show God in the act of creating a finite and temporal universe out of the void.

The 2001 *Book of Nothing* is due to the prolific John Barrow, a research professor of mathematical sciences at the University of Cambridge, an internationally known cosmologist, and an enlightening science writer. He also directs the Millennium Mathematics Project, which aims to raise public understanding of mathematics (see `http://mmp.maths.org/`). Although Barrow does not refer to his rather unknown predecessor, his book draws on a rich cultural background in history, literature, philosophy, religion,…and, of course, science.

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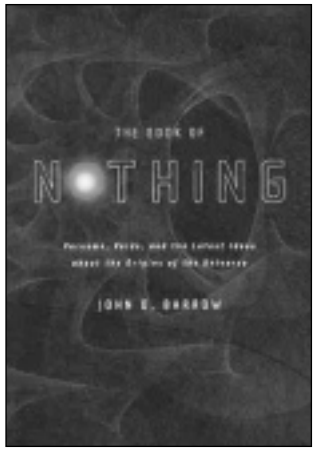

Through 280 pages of text, twenty pages of quotes, 100 or so diagrams, followed by fifty pages of notes, Barrow takes the reader on a journey through history and science to explain every aspect of nothingness. From the zeros of mathematicians to the void of philosophers, from Shakespeare to the null set, from the ether to the quantum vacuum, his book tells how discoveries in science have revealed that Nothing has hidden depths.

The book starts out with historical perceptions of nothing and zero, noting that the very concept was taboo in many places; the Greeks and the Romans did not have a zero in their number systems, and hence Europe for many centuries could not represent it. The zero of the current numeral system originated in India and was put into practice by the merchants of the flourishing medieval Arab civilization, whence it entered Europe in the late Middle Ages. From then, the mathematical zero triumphed because of its usefulness. The notion of a physical zero, however, did not enter the mindset until the physicists Torricelli and von Guericke, in the seventeenth century, removed all the air out of chambers, thereby producing the first laboratory demonstrations of vacuums.

For over three centuries the idea of "empty space" was a staple of human thought until shattered with the arrival of quantum theory in the twentieth

century, with all its bizarre but entirely verifiable implications. Most especially, the uncertainty principle in energy and time tells us that there is a longest time interval available for the energy determination of a system in a given state. Such a law thus expressly forbids a system from assuming any definite energy, which a total vacuum (with zero matter and zero energy) would patently violate. Thus, in contrast to the traditional concept of the primeval void, the quantum vacuum is like a virtual ocean whose surface is continuously agitated by ripples of energy. These ripples can spontaneously generate pairs of particles and antiparticles, which disappear almost as soon as they appear, leaving behind a sort of bubbling brew of energy, in constant flux, the "space-time foam". Occasionally the ripples create particles and antiparticles that are far enough apart not to cancel each other out. This is how matter emerges from the vacuum.

These phenomena have genuine effects on the observable world and on the results of experiments. There is the Casimir effect, for example, a small attractive force that acts between two close parallel uncharged conducting plates, due to quantum vacuum fluctuations of the electromagnetic field. Barrow shows well the many ways now recognized in which something can indeed arise from nothing. For instance the idea of the null set generating numbers, with a neat ironic analogy to how universes are perhaps created out of the vacuum, makes worthwhile reading.

For the remainder of the book, Barrow concentrates on cosmology. Today, many astronomers suspect that vacuum effects may have triggered the Big Bang itself, filling our universe with matter. Indeed, the very latest observations suggest that vacuum effects will dictate the ultimate fate of the universe. Quantum cosmology, based on the general theory of relativity and quantum physics, is an attempt to explain in mathematical terms how the universe suddenly emerged from the quantum vacuum. Some physicists have suggested that in its initial state the quantum vacuum was not at all homogeneous. According to this hypothesis, many different universes were created by different types of fluctuations, each with its own physical properties, each in parallel with or embedded within the others so that no communication between them was possible, except through hypothetical "wormholes".

Barrow does a good job of presenting the mind-boggling idea that our universe may be but one of an infinite number of universes all popping probabilistically out of the vacuum. But problems arise when Barrow ponders the implications this idea holds for the overall structure of the universe. The so-called cosmological constant, which seems to be opposing gravity and pushing the galactic superclusters apart, is of unknown nature and origin. Barrow makes a very good historical point on page 185 when he recalls the insight of Lemaître, who as early as 1931 interpreted the cosmological constant as originating in the behavior of matter at very high energies. The cosmological constant may or may not be related to the energy field of the vacuum, but Barrow mixes the term with other concepts such as vacuum energy, dark energy, and quintessence and seems to say many different things about it. As a consequence, his presentation is rather confusing.

For instance, Barrow tries to figure out how the apparent repulsive force is affecting the cosmic expansion and discusses the implications for the future tendencies of the universe. All of the scientific journals show that this is a hotly debated topic full of question marks about the factors we already know, let alone the myriad considerations that we are still unsure about or have not yet thought of. Barrow basically ignores these issues and provides an oversimplified picture.

The most disputable part of the book concerns the notion, supposedly derived from the quantum-mechanical concept of wavefunction collapse of alternate possibilities, that, given sufficient time, every possibility will manifest itself. In reference to the possible eternal expansion of our particular universe, Barrow notes on page 300 that "[w]hen there is an infinite time to wait then anything that can happen, eventually will happen." Applying this deduction to that possible infinity of universes, one finds a companion to the "many worlds" interpretation of quantum mechanics in which a new universe is created with every quantum event. This companion interpretation asserts that in an infinite universe every possible event will take place, and every thought unthought will eventually be thought, that indeed there are unicorns somewhere and politicians who do not lie, and a place where bread always lands butter side up.

This idea is not new and, as already pointed out by many researchers, is basically a misinterpretation of the probabilistic nature of quantum mechanics: Even though the set of possible occurrences that become actual does become larger and larger with time, the pool of possibilities increases even more rapidly. Moreover, the extrapolation breaks down when one considers different arrangements of the actualizations; it is basically a confusion about applying set theory to physics. Such applications should be more modestly utilized.

If Barrow had simply been more careful to acknowledge the speculative nature of the cosmological topics or just allowed for a few more well-placed "we do not know the answers", the later sections of the book would have been of higher quality.

To summarize, Barrow's book is an outstanding work that seems rushed in its most speculative parts. His thesis is that nature really does abhor the vacuum in the most concrete physical sense: The old notion of a complete void, of empty space, is colossally wrong. The cosmos as revealed by modern astronomy, astrophysics, relativity, quantum mechanics, and the ideas from string theory is a story of breathtaking and mind-boggling sweep and grandeur, often totally unintuitive and beyond the lay reader's wildest imaginings. As picturesque, inventive, and psychologically satisfying as the ancients' tales of the cosmos are, they pale beside the conception of the universe as seen by modern science. Perhaps the main merit of Barrow's *Book of Nothing* is to exemplify the contrast between the ancient lore about the creation of the universe and the modern scientific view.