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RECENZJA / BOOK REVIEW

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From the Edge of Time to the Infinite Future of the Universe

Paul DAVIES, **What's Eating the Universe? And Other Cosmic Questions**, The University of Chicago Press, Chicago 2021, pp. 184.

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This book written by Paul Davies ¹ — physicist, cosmologist, astrobiologist, and popular writer — is a collection of thirty very brief essays (each consisting of a few pages) about contemporary cosmology and some philosophical problems raised by the latter. The author explains “how age-old puzzles have recently been solved while startling discoveries are upending our understanding of physical reality” (p. vii). This is a journey from the edge of time to the infinite future of the universe, a popular study in cosmology, the science of the beginning and evolution of the universe.

Cosmology is a relatively young science: it only gained the status of scientific discipline *par excellence* in the 1920s. Previously, questions about the onset and evolution of the universe had, for millennia, resided exclusively in the domains of religion and philosophy. Nowadays, those questions are receiving scientific answers thanks to mathematics, telescopes, and elementary particle accelerators. In modern cosmology, research into the large-scale structure of the universe is com-

¹ This book has been translated into Polish: **Co pożera Wszechświat? I inne zagadki kosmosu**, transl. Tadeusz Chawziuk, Copernicus Center Press, Kraków 2022.



bined with research into the elementary components of matter. In addition to reviewing the most important achievements of cosmology, Davies also raises fundamental philosophical questions. Why does the universe exist at all? Why does it have the form it does? Why are the laws of nature as they are? How did a system of mindless, purposeless particles bring forth conscious, thinking beings who can make some sort of sense of their world? (p. vii-viii).

According to Davies, a golden age of cosmology was initiated by the sky map of the microwaves obtained by the satellite Cosmic Background Explorer (COBE) in 1990. This image shows us “nothing less than the birth of the universe” (p. 1). “In the three decades since, the field has been transformed from a speculative backwater to a precision science” (p. 1).

The classical picture of the universe, formed by Newtonian physics, leads to several problems. In accordance with Newton’s law of gravitation, any particle of matter in the universe attracts any other with a force varying directly as the product of their masses and inversely as the square of the distance between them. Why, therefore, did the stars not fall together into one great mass? The second problem, called Olbers’ (or the dark night sky) paradox, is included in the question “why is it dark at night?”. A static, infinitely old universe with an infinite number of stars distributed in an infinitely large space would be bright rather than dark. There is a third problem, not mentioned by Davies, namely the heat death of the universe. According to the second law of thermodynamics, heat always flows spontaneously from a hotter to a colder body. Every system in the universe evolves in the direction of thermodynamic equilibrium. An extrapolation of the second law of thermodynamics on a universal scale led to the conclusion that an infinitely old universe would achieve thermodynamic equilibrium in the form of what is known as heat death.

In the 1920s, most scientists believed in an unchanging and static universe. In 1917, Albert Einstein added the cosmological constant to his general relativity equations, to achieve a model of a static universe, a notion which was the accepted view of the time. Years later, he considered it “the biggest mistake in his life”. (Nowadays, astronomers have accepted Einstein’s cosmological constant in a different context to explain the acceleration in the expansion of the universe). In 1929, Edwin Hubble discovered red shift, which means that distant galaxies are moving away from us. The universe is expanding. This means that at earlier times objects would have been closer together. The discovery brought the question of

the beginning of the universe into science. Hubble's discovery suggested that there was a time when the universe was infinitely small and infinitely dense. Davies writes about the theoretical works of Aleksandr Friedman, Georges Lemaître, George Gamow and Robert Dicke. The discovery of microwave background radiation was an important development in modern cosmology. In 1964, Arno Penzias and Robert Wilson, while "working on satellite communications at the Bell Laboratory in New Jersey accidentally came across this remnant heat, bathing the universe at a temperature of about 2.7 degrees above absolute zero". It is puzzling that Davies does not mention the names of Penzias and Wilson (their names are not even in the index), referring instead simply to "scientists working on satellite communication at the Bell Laboratory in New Jersey" (p. 22). In 1978, Penzias and Wilson were awarded the Nobel Prize for Physics. Their discovery was a breakthrough as far as acceptance of the Big Bang Theory was concerned.

Nowadays, the Big Bang Theory is commonly accepted. It states that the universe came into existence roughly 13.8 billion years ago. At this time, all matter was compacted into a very small ball with infinite density and intense heat, called "the singularity". The singularity began expanding, and the universe as we know it began.

Davies describes the most important stages in the evolution of cosmology while paying attention to some philosophical problems related to them. For example, for centuries philosophers and scientists have wondered whether the universe is spatially finite or infinite. However, according to the theory of relativity, the speed of light in a vacuum c is a universal physical constant, and c is the upper limit at which any signal carrying information can travel through space. A cosmological horizon is a measure of the distance from which one could retrieve information. It establishes the size of the observable universe. "There is a horizon in space", writes Davies, "restricting our view. And because nothing can go faster than light there's no way to know for sure what lies beyond [...]. The horizon is simply the boundary of our visible cosmic patch. The universe may very well be infinitely extended in space, but if it is finite in time, we can't look to see" (p. 26). Similarly, a black hole is surrounded by an event horizon "so named because we cannot know from outside what happens inside" (p. 75). The title of the book, **What's Eating the Universe**, alludes to black holes that "swallow everything and give nothing back" (p. 75).

Modern cosmology is a fully mature science, which is not to say that it is devoid of theoretical problems. All the chemical elements from hydrogen to uranium make up only about 5% of the mass of the universe. In the standard cosmological model, the content of the universe contains 27% dark matter, and 68% dark energy. Dark matter interacts with ordinary baryonic matter only through gravity. There is no agreement among scientists about what dark matter consists of. The candidates for dark matter — weakly interacting particles (WIMPs) and axions — have not been detected. It is not known what dark matter is. Observational evidence has shown that the universe does not expand at a constant rate; rather, the universe is expanding faster and faster. Dark energy is probably the form of energy responsible for causing the universe's rate of expansion to accelerate. It is also not known what dark energy is. Furthermore, the Big Bang should have created equal amounts of matter and antimatter. However, everything we observe is made almost entirely from matter. Why do we therefore see an asymmetry between matter and antimatter? The causes of this asymmetry are unknown.

After discussing the problem of symmetries in elementary particle physics, Davies poses an interesting philosophical question: “why are there *any* asymmetries in the laws of nature?” (p. 65). Many scientists believe that “nature must be both simple and elegant. Symmetry is undeniably a factor in beauty” (p. 67). The problem of the role of aesthetic values in physics and cosmology have been widely discussed recently. For example, Sabine Hossenfelder, in her book **Lost in Math: How Beauty Leads Physics Astray**, analyses the role in elementary physics of such aesthetic criteria as naturalness, simplicity or elegance, and beauty. She notes that “in the absence of guidance from experiments, theorists use aesthetic criteria”,² and observes that “Scientists have used beauty as a guide for long time. It hasn't always been a good guide”.³ Moreover, Davies asserts that “beauty is in the eye of the beholder” (p. 67).

Davies also analyses the problem of the arrow of time and the possibility of

² Sabine HOSSENFELDER, **Lost in Math: How Beauty Leads Physics Astray**, Basic Books, New York 2018, p. 16.

³ HOSSENFELDER, **Lost in Math...**, p. 41. See also Andrzej ŁUKASIK, „Czy w nauce jest miejsce na kategorię piękna?” (Book review: Sabine HOSSENFELDER, **Lost in Math: How Beauty Leads Physics Astray**, Basic Books, New York 2018; Polish edition: Sabine HOSSENFELDER, **Zagubione w matematyce. Fizyka w pułapce piękna**, transl. Tomasz Miller, Copernicus Center Press, Kraków 2019), *Filozoficzne Aspekty Genezy* 2021, Vol. 18, s. 229–236, <https://doi.org/10.53763/fag.2021.18.3>.

time travel. What is the source of the asymmetry between past and future? Of course, we remember the past and not the future, and we feel we can influence the future but not the past. “Imagine taking a movie of an everyday incident and playing it in reverse to an audience. Everybody laughs because it looks so preposterous” (p. 83). However, the problem is that the fundamental laws of physics are invariant with time inversion. Davies discusses the notion of entropy in thermodynamics, time’s arrow in cosmology and elementary particle physics. He concludes: “All that can be said for certain is that one of the most fundamental properties of the physical world — that tomorrow is different from yesterday — still lacks a full explanation, and it lies high on my own list of essential, unanswered big questions” (p. 87). Time travel is the subject of many science fiction novels and movies, but it turns out that it can also be discussed on the basis of contemporary physics. In 1948, Kurt Gödel produced a solution to Einstein’s general relativity equation “that did indeed allow observers to travel into their own past” (p. 81). Although physically possible, time travel implies some paradoxes, such as the “grandfather paradox” or causal loop paradox.

After discussing the fundamental problems of the Standard Model and the difficulties related to the search for a “theory of everything”, Davies discusses the concept of the multiverse, and the anthropic principle. He analyses various answers to the question of why our universe seems to be “just right” for life (p. 124), and the question of whether we are alone in the universe. His considerations conclude with a discussion of scenarios for the ultimate fate of the universe, and some remarks about the scientific method in general. “Both relativity and quantum theory”, writes Davies, “succeeded by fundamentally altering the entire conceptual framework of the subject matter. I suspect that some problems faced by physicists and cosmologists today likewise require a radical overhaul of existing concepts” (p. 163).

What’s Eating the Universe is undoubtedly a very interesting book. Davies presents a concise summary of the latest state of research in cosmology and elementary particle physics, and shows us the links between exact science and many significant philosophical problems. Physicists can explain the evolution of the universe as far back as the first split second. It’s one of the greatest scientific achievements. So far, it has not been possible to combine quantum mechanics with general relativity and formulate a “theory of everything” (TOE, or quantum gravity). However, in **A Brief History of Time**, Stephen Hawking has written that “if we do

discover a complete theory, it should in time be understandable in broad principle by everyone, not just a few scientists. Then we shall all, philosophers, scientists, and just ordinary people be able to take part in the discussion of the question of why it is that we and the universe exist. If we find the answer to that, it would be the ultimate triumph of human reason — for then we would know the mind of God”.⁴ Davies would probably agree with that view.

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⁴ Stephen HAWKING, **A Brief History of Time**, Bentam Books Trade Paperbacks, New York 1998, p. 171.