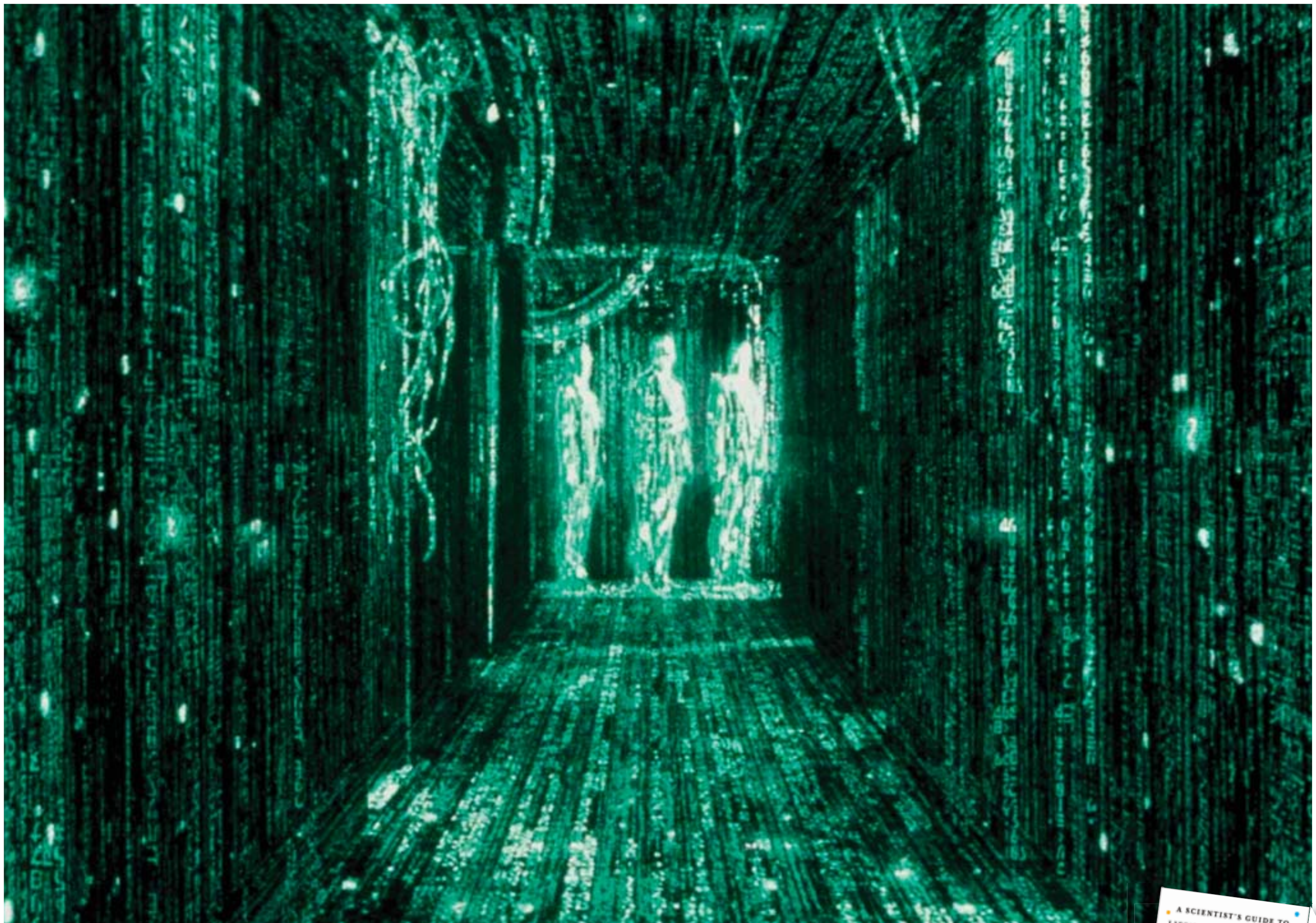

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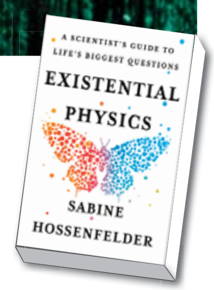
The 1999 film *The Matrix* famously made mainstream the hypothesis that our reality may actually be a simulation constructed by a superintelligence.

A physicist gets philosophical

Existential Physics
A Scientist's Guide to Life's Biggest Questions
Sabine Hossenfelder
Viking, 2022. $28.00



Sabine Hossenfelder's provocative first book, *Lost in Math: How Beauty Leads Physics Astray* (2018), garnered a lot of well-deserved attention for its blunt and largely compelling argument: An overreliance on mathematical elegance and a nonchalance about the want of empirical evidence, she contended, had pointed fundamental physics down a yellow-brick road that led not to the Emerald City but to a fantasy land of speculative alternatives to the standard model, none of which have yet found a toehold on the firm ground of empirical reality.

Although it is aimed at a different audience and engages with a different set of questions, her delightfully provocative new book, *Existential Physics: A Scientist's Guide to Life's Biggest Questions*, is equally blunt. It speaks to a general audience of readers who want to know, for example, whether our best current science sheds any light on such deep and important questions as how the universe began, whether it was designed by God to be a comfy home for humans, whether we humans are part of a simulation constructed by a superintelligence, and whether human intelligence could reside equally well in a machine.

Hossenfelder works hard to be a fair arbiter and to respect the motivations behind those questions. Her most frequent response is that science is neutral, which means that the answers hoped for by some and sometimes boldly proclaimed by others, including eminent scientists like Richard Dawkins and Lawrence Krauss, are at best "ascientific." But when the evidence is clear, Hossenfelder doesn't shy away from declaring that some cherished beliefs are simply ruled out by science. Partly for reasons of style, my favorite example of that latter kind is in her chapter on the existence of free will. After considering the question from a variety of perspectives, she wraps up the discussion of each by repeating a simple mantra: "The future is fixed except for occasional quantum events that we cannot influence."

On only two points would I want to quibble. The first concerns Hossenfelder's discussion of wavefunction reduction, which she introduces in chapter 1, "Does the Past Still Exist?," as one of only two exceptions to the time-reversal invariance of our fundamental dynamical equations (the other is black hole evaporation). Although she acknowledges the longstanding puzzlement over whether measurement is a well-defined concept and whether measurements can therefore play a physically unique role in nature, Hossenfelder nonetheless at first asserts that the question of wavefunction reduction has "largely been answered," suggesting that it is a matter of established fact that the phenomenon really occurs, and defines a measurement as "any interaction that is sufficiently strong or frequent to destroy the quantum behavior of a system."

The first problem with that description is that most decoherence theorists would deny that the quantum behavior is destroyed, which it cannot be because the decoherence dynamics is linear, Schrödinger dynamics. Those theorists would argue that in all but a few cases, the quantum behavior is driven so deeply into hiding as not to reappear within the likely lifetime of the universe. The second problem is that two pages later, Hossenfelder writes, "If you don't believe the measurement update is fundamentally correct, that's currently a scientifically valid position to hold." She adds that she herself believes that wavefunction reduction will be replaced by a physical process in a future, underlying theory that will restore determinism and time-reversal symmetry. If so, the question of wavefunction reduction has not "largely been answered."

My second quibble concerns the discussion of reductionism and quantum entanglement in chapter 4, "Are You Just a Bag of Atoms?" On the whole, Hossenfelder's defense of a strong form of ontological reductionism is a good one, and one with which I largely agree. Her main point is that the evidence shows "that things are made of smaller things, and if you know what the small things do, then you can tell what the large things do."

But deep down at the quantum level, that is not so, because when two or more systems become entangled with one another through an interaction, the post-interaction state of the joint system cannot be written as a product of separate states for the subsystems. In other words, $\psi_{12} \neq \psi_1 \otimes \psi_2$. There is no more scientifically well-established example of holism—the idea that the whole is more than the sum of its parts—than that. So when Hossenfelder writes that entanglement "doesn't contradict reductionism," she's wrong. Does that make for a serious problem with the larger argument for reductionism? Does holism extend up the ladder of scale to the macroscopic level? That is a hard and open question. But I am still mainly on Hossenfelder's side.

I do not want to leave a misimpression. I really enjoyed *Existential Physics*, and you will too. It is engaging, informative, and accessible to the nonspecialist. The spirit of frank but open and sympathetic dialogue with people who might be discomfited by what science is teaching us should stand as a model for other scientists who sincerely want to make their science relevant to the concerns of a broader public.

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