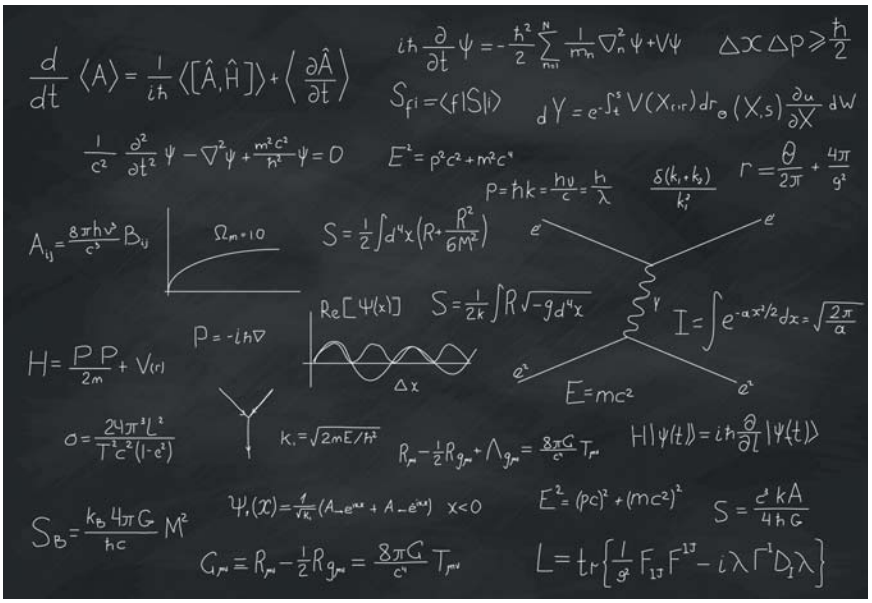


IKONSTUDIO / ISTOCK / THINKSTOCK

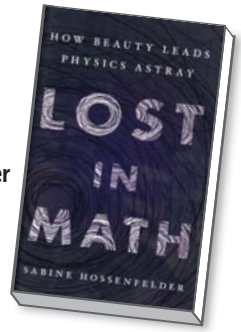
Has elegance betrayed physics?

Sabine Hossenfelder's *Lost in Math: How Beauty Leads Physics Astray* is an unusual book, at once intensely personal and intellectually hard-edged. Although I disagree with it on many points, I recommend the book both as a well-written, moving intellectual autobiography and as an excellent exposition of some frontiers of foundational theoretical physics, largely told through dialogs with leading figures in the field.

Theoretical physicist Hossenfelder is both passionate about the mission of her science and disappointed about its recent history. In the first paragraph of the book, she says of her field, "In the temple of knowledge, we are the ones digging in the basement, probing the foundations. . . . And when we find ourselves on to something, we call for experimentalists to unearth deeper layers. In the last century, this division of labor between theorists and experimentalists worked very well. But my generation has been stunningly unsuccessful."

Hossenfelder diagnoses the problem as overreliance on beauty as a guide to how the world works. Looking back on 20 years of effort in the pursuit of new physical laws, she recounts a sad litany of frustrations and unfulfilled prophecies. The standard model of particle physics remains what it has been since the 1970s: a powerful and brilliantly successful foundational description underlying all the observed phenomena of nature that nonetheless leaves many loose ends.

Lost in Math
How Beauty Leads Physics Astray
Sabine Hossenfelder
Basic Books, 2018.
$30.00



Supersymmetry (SUSY), widely hailed as a great step forward in unifying our description of nature, has failed to materialize at the Large Hadron Collider despite a decade's worth of experimentation and anticipation. Dark matter has yet to be identified despite enormous efforts to detect weakly interacting massive particles (WIMPs)—the candidates suggested by SUSY—or other compelling possibilities such as axions. Nor has the nature of dark energy been elucidated. Hossenfelder might also have added the failure to observe proton decay, a central prediction of mainstream unified field theories. String theory has failed to deliver concrete predictions, let alone successful ones, as have other, less heralded high-theory approaches.

While no part of that gloomy story is entirely wrong, it is seriously incomplete, and it features some premature burials. The past 30 years have been a golden age for physical cosmology. Although proton decay has not been observed, we have detected another primary prediction of a unified field theory, small neutrino masses. The Higgs particle was discovered and its detailed study has begun. The era of gravitational-wave astronomy, full of promise, has commenced. SUSY, proton decay, WIMPs, and axions are still very much live possibilities that continue to inspire hard experimental work and ingenuity around the world. And high theory has not totally abandoned the aspiration to describe physical reality.

Still, the malaise expressed by Hossenfelder is not baseless, and it is widely shared among physicists. But her diagnosis, that a search for beauty is limiting our vision, strikes me as odd. Let me insert a few words in defense of beauty. Symmetry is at the core of the standard model and helped us to discover it. Modern physical cosmology also pivots on symmetry and simplicity, both in its general relativistic foundations and in its choice of initial conditions. Also, the systematic use of beautiful ideas from topology has been an extremely fruitful source of inspiration for condensed-matter physics, and beautiful ideas from information theory are illuminating physical algorithms and quantum network design. We need more beautiful ideas, not fewer.

Hossenfelder's real target, when you strip away some unfortunate terminology, is not beauty but self-satisfaction, which encourages disengagement from reality. That attitude reaches its theoretical apex in the doctrine of "postempirical science," which argues that social consensus, not experimental evidence, determines scientific validity. Here she quotes physicist George Ellis, rebuking physicists and philosophers who adopt that attitude: "There are physicists now saying we don't have to test their ideas because they are such good ideas. They're saying—implicitly or explicitly—that they

want to weaken the requirement that theories have to be tested. To my mind that's a step backward by a thousand years."

In my view, the slow pace of new discoveries in fundamental physics is to a large extent the natural outcome of our earlier, spectacular success. It's been hard to make improvements. Patience may be required. In fact, we've already learned that it will be. The good news is that there's much more to physics, and to life, than digging deeper foundations.

Frank Wilczek
Massachusetts Institute of Technology
Cambridge

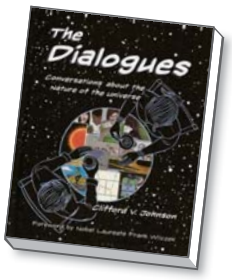
A graphic textbook imagines conversations about physics

A common misperception about comics is that the medium is childish and best left to newspaper strips or depictions of superheroes. That view fails to acknowledge how the powerful combination of text and visual depictions in comics can draw readers in and keep them engaged with a profound or complex story. The recent rapid expansion of comics into STEM (science, technology, engineering, and mathematics) teaching and storytelling has demonstrated the medium's potential. Apostolos Doxiadis and Christos Papadimitriou's *Logicomix* (2009) was a fascinating dive into the life and work of philosopher and mathematician Bertrand Russell; the Science Comics series from Macmillan has produced volumes dense with facts but endearing to read; and artists like Maki Naro and Rosemary Mosco have blended science and comics to make complicated concepts more accessible to all readers.

The Dialogues: Conversations about the Nature of the Universe by University of Southern California physicist Clifford V. Johnson attempts to use the same combination of narrative and art to open up physics. The book—"graphic textbook" is the term that feels most appropriate—depicts one-on-one conversations involving a series of characters. Johnson's conversationalists discuss concepts running the gamut from Maxwell's equations to infinity, hypothesis, and experimentation.

The conversations in *The Dialogues* mostly take place between a scientist and a person on the street. The locations vary: a museum, a coffee shop, and a train, to name a few. The scientist responds to questions or skepticism and explains complicated theories. Often the conversations end with some questions left unanswered, perhaps an attempt to pique readers' interest and encourage them to undertake further study and consideration. If a book like *The Dialogues* had no art, the conversations could seem one-sided, giving the effect of a narrator rather straightforwardly addressing the reader. The comics format, however, allows Johnson to interweave into his text questions that the reader might ask; in a sense he integrates the readers themselves into the dialogues.

The Dialogues
Conversations about the Nature of the Universe
Clifford V. Johnson
MIT Press, 2017.
$29.95



The characters are diverse in age and understanding, which can lead to abrupt shifts in tone from chapter to chapter. Moving from a young girl analyzing how rice expands while cooking to a discussion of relativity and spacetime with an adult fan of science does create an interesting sense of narrative progression. The varying levels of scientific discussion, however, make it unclear who the book is intended for.

The greatest problem with graphic works is that the art must effectively support the story. The art must be engaging in its own way, as bad art can be just as detrimental to the novel or textbook as a