

In the 1E 0657-56 galaxy cluster, ordinary matter is shown in pink. Blue indicates most of the mass of the cluster — presumed to be dark matter.

COSMOLOGY

# Matter and mixology

Francis Halzen is exhilarated by an account of the hunt for the particles of dark matter.

The juggernaut that is precision cosmology has uncovered a strange Universe: 7 parts dark energy, 2.5 parts dark matter and 0.5 parts hydrogen and helium gas (with traces of other chemical elements). The stars and neutrinos, microwave photons and supermassive black holes that constitute the rest do not add up to very much. *The Cosmic Cocktail* by astrophysicist Katherine Freese tells us how we got to this bizarre recipe, what it might mean and what could come next.

The book itself is a cocktail, mixing science and autobiography. When the flood of facts and explanations threatens to overwhelm the reader, Freese delights us with vignettes of her personal life. So we get accounts of her favourite places to drink and dance in New York City or to ski in Aspen, Colorado, as well as entertaining stories about the work of dark-matter hunters she has met and collaborated with, such as Bernard Sadoulet and Juan Collar. Her portrait of astroparticle pioneer David

Schramm, who in 1997 tragically died while flying his plane home for Christmas, is touching. It all works because, in prose as in life, Katherine Freese is never boring. Hers is an insider's view of how cosmology has been transformed since the 1960s, from a niche science to a discipline that pushes the intellectual frontier of physics — a development in which Freese has had an active and prominent role.

Ever the master mixologist, Freese gives us a sequence of clear and accessible introductions to the key concepts of cosmology and its observational techniques. The approach is never superficial and often quantitative. The treatment of nucleosynthesis is a gem, laying out how

the nuclear physics of the early Big Bang left us with a Universe whose ordinary matter is made mostly of hydrogen and helium. Even the ratio of these gases is computed, at the price of introducing two of the very few equations in the book.

Much of the narrative focuses on the hunt for dark matter. The nineteenth-century French astronomer Urbain Le Verrier proposed the existence of a new planet, Vulcan, to explain strange wanderings in the orbit of Mercury. He was wrong, it transpired, because he was using an outdated theory — Newtonian gravity rather than Einstein's general theory of relativity. One might wonder whether the strange apparent composition of the cosmological cocktail hints, in turn, at the demise of Einstein's masterpiece. But Freese strongly argues that dark matter is not the Vulcan of general relativity, and that the search for its particle constituents will eventually find success.

The centrepiece of the book is the search for dark matter's particles. Starting with Fritz



**The Cosmic Cocktail: Three Parts Dark Matter**  
KATHERINE FREESE  
Princeton University Press: 2014.

NASA

Zwicky in the early 1930s, astronomers have built a conclusive case for the existence of dark matter. Its presence is inferred from its gravitational pull on stars in the Milky Way, and on whole galaxies in galaxy clusters. As with the neutrino, we are not aware of its existence: we do not feel or see it. In fact, neutrinos with an appropriate mass were once

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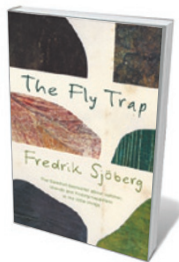
thought to make up dark matter, but this attractive idea — neutrinos do exist, after all — does not create the Universe that our telescopes observe.

Also like neutrinos, dark-matter particles do not interact with normal matter, or not very much. More than two decades of intensive searching have not yet brought a discovery, but have instead measured an upper limit on the cross-section, or probability, of a dark-matter particle interacting with ordinary matter. Freese dramatically describes the highly competitive race to the smallest cross-section limit, introducing the main players and their wide-ranging instrumentation. Because instruments are made from ordinary matter, they are not generally affected by the passage of a dark-matter particle. For even the slightest chance of success, one must build detectors of enormous size or develop increasingly imaginative detection techniques — preferably both. In most detectors today, the hope is that a dark-matter particle will bounce off a nucleus in a detection medium, producing recoil and generating a tiny amount of light or heat, which detectors can then harvest to infer the particle’s existence. It is not a race to the bottom, however, and a discovery — with its guaranteed Nobel prize — could be around the corner at any time.

*The Cosmic Cocktail* is an excellent primer for the intrigued generalist, or for those who have spent too much time in particle-physics labs and want to catch up on what cosmologists are up to. The book will undoubtedly inspire students, too. It exposes the two great secrets about science that solar-neutrino guru John Bahcall often mentioned in his lectures: science is addictive, and unpredictable. It proceeds with detours, dead ends, false alarms, missed opportunities and surprises. And one day, someone might run into dark matter. ■

**Francis Halzen** is the principal investigator of the IceCube South Pole neutrino observatory, and Hilldale and Gregory Breit professor of physics at the University of Wisconsin-Madison.  
e-mail: francis.halzen@icecube.wisc.edu

## Books in brief



### The Fly Trap

Fredrik Sjöberg (Translated by Thomas Teal) ALLEN LANE (2014)

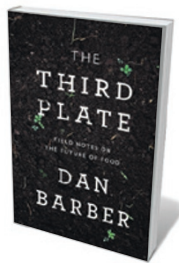
A shimmering and elusive grace pervades Fredrik Sjöberg’s evocation of his life and work as a hoverfly expert. This Swedish best-seller deftly interweaves three threads: the intricate business of fieldwork tracking and trapping flies in the Stockholm archipelago; the life of sawfly expert, art collector and sometime crackpot René Malaise; and a wealth of cultural allusions. Sjöberg is mesmerizing, whether describing the psychology of collecting, hoverflies as “superb impostors” or the moment a maple blooms in greenish glory — when “everything flies, absolutely everything”.



### The Sick Rose: Disease and the Art of Medical Illustration

Richard Barnett THAMES AND HUDSON (2014)

Can a panoply of horrors become a thing of beauty? Richard Barnett would have you think so. He has collected scores of appalling, if brilliantly rendered, illustrations from eighteenth- to twentieth-century medical textbooks and other sources, to explore a period in which medicine moved conclusively away from its unscientific past. In his view, images of syphilitic sores and horrifically eroded faces can and should be considered legitimate art as well as historical artefacts. A fascinating book, albeit only for those with strong stomachs.



### The Third Plate: Field Notes on the Future of Food

Dan Barber PENGUIN (2014)

Mapping the provenance of meat and produce — the “farm to table” approach — is now part of the Western food-sustainability paradigm. Lauded chef Dan Barber calls for a more radical shift. His finely orchestrated agricultural model incorporates crop biodiversity and rotation, mixed land use, diverse livestock diets, ethical fishing and a realignment of US eating habits towards ‘whole food’ cuisine, including ‘nose-to-tail’ consumption of animals. An inspirational agronomic model — but given the dominance of industrial agriculture in the United States, it may smack of the utopian to some.



### The Paper Trail: An Unexpected History of the World's Greatest Invention

Alexander Monro ALLEN LANE (2014)

Paper may be derided as a waste of trees, and as dead as the dodo in our digitized world. But, as Alexander Monro reminds us in this erudite history, it has been the base layer of world culture. Monro traces paper’s trajectory from its second-century-AD origins in China to its passage through Eurasia, the Maghreb and on to world dominance. From Islamic scientific tracts to Copernicus’s 1543 *De Revolutionibus*, paper, as Monro eloquently shows, has filled the supremely important role of placing “truth in the reader’s hands”.



### The Next Crash: How Short-Term Profit Seeking Trumps Airline Safety

Amy L. Fraher CORNELL UNIVERSITY PRESS (2014)

The 700 million people flying in the United States this year might face unexpected turbulence, argues former naval aviator Amy Fraher. Her history of the US aviation industry — including hundreds of interviews with professionals — reveals cost-cutting and lax oversight in recent years. Short-term gain is trumping long-term safety: in 2000–12, carriers earned US\$2 trillion, yet risk management is not keeping pace with rapid shifts in the industry. **Barbara Kiser**