Later in the text Pal's approach to field theory is decidedly that of a phenomenologist; so he does not get swamped in half-cooked discussions on too many 'theoretical' matters, but he does have clear discussions of instantons, anomalies, large-N theories and lattice gauge theory (among other things).

The biggest strength of this book is its pedagogical clarity. It comes in superficially intimidating at around 800 pages, but I think this should not deter the reader from taking it on – in many ways the size is an artifact of the care that is paid in the clarity of presentation, a thinner book would have been harder and longer to read. Another related feature of the book is that the computations are often done in enough detail, so that one can often read through the book to a degree without getting bogged down in too much pen and paper. Apart from the pedagogical value for novices, the later chapters of the book are interesting for active high-energy physicists as well (at least those who are not too closely involved with particle phenomenology, like the present reviewer). The discussions on loop effects, custodial symmetry, Peskin–Takeuchi parameters, CP violation and various aspects of neutrinos stood out as particularly clarifying.

Now that the review of the subject matter is out of the way, let me talk about a few stylistic features of the book that I found jarring. One is the typesetting – there are way too many font-types inside the book, which gives some pages a rather dog's breakfast-like look. But the author is clearly aware of the outrage his typesetting idiosyncrasies cause among his colleagues (he says as much in one of the paragraphs in the preface). I am also one of those who is outraged by this – in my defence, it is not so much the specific fonts that I found irksome, but the bad *feng-shui* that they produce on a page when mixed together (seemingly) erratically. The printing and production of the book is well done by CRC Press, so it does somewhat compensate for the chaotic fonts.

Another (minor) personal peeve that I have with the book is that at various points, it manages to convey a certain adoration that goes beyond mere respect towards Lincoln Wolfenstein, Pal's Ph D advisor. Clearly Wolfenstein is a great physicist, but pedestalizing our (obviously worthy) idols, gives the impression that the only place for us to stand, is below. In a world where fundamental theory is increasingly global, it is perhaps more important to humanize the greats – not the least because the heroes of the last generation often belonged to a different race, place, sex or caste, and they are often already larger than life in the eyes of an aspiring student.

But these are all minor nits to pick – as a textbook, Palash Pal's tome on particle physics is accessibly written for serious beginning students, and is a great addition to the bookshelves of seasoned scientists interested in the phenomenological foundations of the Standard Model.

CHETHAN KRISHNAN

Center for High Energy Physics,
Indian Institute of Science,
Bengaluru 560 012, India
e-mail: chethan@cts.iisc.ernet.in

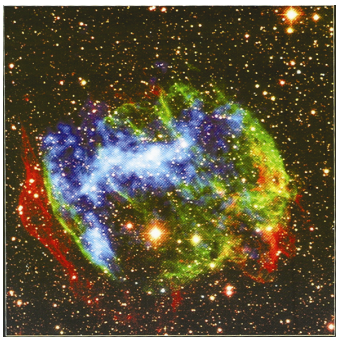
The Cosmic Cocktail: Three Parts Dark Matter. Katherine Freese. Princeton University Press, 41 William Street, Princeton, New Jersey 08540, USA. 2014. xi + 250 pp. Price: US$ 29.95.

Dark matter is an enigma of modern astrophysics. About a third of the total mass energy of the universe is believed to be made up of something that gravitates but does not shine. Another two thirds is thought to be composed of yet another intriguing substance called the dark energy. The type of matter that we normally encounter constitutes a tiny 4%.

Are these ideas for real, or do they represent a desperate attempt to explain the observations with incomplete or wrong theories? In this candid book, Freese tackles these questions, beginning with the story of the research on this topic that she interweaves with her personal narrative. She was one of the first physicists to think about possible ways of detecting dark matter particles, and her story provides an interesting backdrop for the history of dark matter theories and experiments.

Although she has been involved in many aspects of developing theoretical models of dark matter particles, and in thinking of extraordinary way of detecting them (one using DNA strands!), her narrative is remarkably forthright. At the end of the book, after describing the present state of confusion among the scientists, she asks: 'Is it possible that dark matter and dark energy don't exist? Could scientists be missing something fundamental? Perhaps an entirely different way of looking at the world will replace the need for these invisible pieces of the Universe.'

Currently, there are a number of ongoing experiments around the world, trying to look for the elusive dark matter particles. No one yet knows what properties (even mass) these particles may have, but as Freese's account tells us, there are some broad ideas. One is to use large particle accelerators, such as the one in CERN that discovered the Higgs particle, and hope that particle collisions would create some dark matter particles. Another idea is to use detectors of some special nuclei which may detect the dark matter particles that are swarming around the solar system in this part of the Milky Way. As the Earth goes around the Sun, these detectors are likely to show an annual modulation (although tiny in magnitude) of the detection rate. Freese was one of the first people to predict and characterize such an expected modulation. An Italian experiment claims to



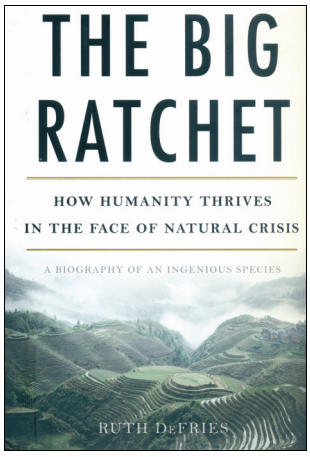
A supernova remnant.

have detected this modulation, but there are some doubts whether or not they are spurious signals. Yet another idea is to look for high-energy photons from astrophysical objects or regions (such as the centre of the Milky Way), which may result from interactions of dark matter particles with themselves or decaying dark matter.

Freese's account is partly at the level of popular science books, and partly a memoir. Her style of writing is engaging, and the anecdotes of conferences and meetings in which new ideas regarding dark matter have come up, make the narrative very readable. Barring a few typos (for example, HESS telescope is mistakenly noted as being located in Europe), this is an interesting addition to the list of books that tells the story of modern physics from the point of view of an active practitioner.

BIMAN NATH

Department of Astronomy and Astrophysics,
Raman Research Institute,
Bengaluru 560 080, India
e-mail: nath.biman@gmail.com



The Big Ratchet: How Humanity Thrives in the Face of Natural Crisis. A Biography of an Ingenious Species. Ruth DeFries. Basic Books, 250 West 57th Street, 15th Floor, New York. 2014. 273 pp. Price: US$ 27.99.

The book under review by Ruth DeFries brings together fascinating dimensions of the human species and its ingenious interaction with nature's endowments in ways vastly different from those of other mammals, including the primates in existence today. Ruth describes the planetary beginnings about 5 billion years ago, and the fortuitous location of the Earth in the habitable zone of the solar system. Not just that. By pathways and processes as yet not fully understood, the Earth also acquired carbon, nitrogen, water and possibly phosphorus. High temperatures and energy provided by the Sun to the primeval Earth produced the primordial soup. It contained the ingredients of the incipient organic molecules that over a period of time developed self-replicating single-cell organisms. This was about 3.5 billion years ago. DeFries refers to it as the first pivot.

At this juncture of the review, a brief introduction to the three words, viz. 'ratchet', 'hatchet' and 'pivot' used extensively in the book would be useful. The *Oxford Dictionary* meaning of 'ratchet' is a wheel with a rim so toothed as to move in one direction only. The author perceives the turn of the ratchet to signify a 'rise' or 'success' of humanity. Availability of plenty of food leads to expansion/multiplication of numbers of the species until food deficit sets in. Food famines and degradation of the environment constitute the 'hatchet'. So, with a hatchet falling, the species once again faces the threat of a collapse unless a new 'pivot' (a new way to use or exploit nature's endowment) emerges. The book is a thought-provoking narrative of the cycles of ratchet–hatchet–pivot of the human (*Homo*) species, a descendant of an African tree-climbing ancestor several millions of years ago. The modern human species, *Homo sapiens* (sapient = wise) is known to have existed in basic raw form about 500,000 years ago. The author describes that a few precursor *Homo* species, with distinguishing characteristic of large brains in proportion to their body weight, viz. *H. habilis*, *H. erectus*, *H. heidelbergensis*, *H. floresiensis* became extinct between 1.5 million and 17,000 years ago.

An interesting distinction between the human species and all the other mammals, including the primates that exist today, is the complexity of civilization subordinating the role of Darwinian natural selection. The author refers to Darwin's famous 1874 treatise, *The Descent of Man* and cites the statement, 'With highly civilized nations, continued progress depends in a subordinate degree on natural selection'. Several others (Theodosius Dabzhansky, Ashley Montagu) who followed Darwin picked up the question of how human culture evolves, and tried to answer the puzzle of how genes and cultures intertwine and co-evolve. One view is that culture would never have evolved unless it could do things that genes could not. These considerations enable a working hypothesis that the human species uses its 'ingenuity' rather than its genes to develop a 'pivot'. The 'pivot' is essentially the outcome of Darwinian selection for all living beings, except the human species. Culture and ingenuity invent the 'pivots'. This basic difference between the human and all other species is possibly the underlying cause of the human dominance over all other forms of life and in fact, the planet itself. A significant pivot resulted about 10,000 years ago, when *H. sapiens* made a transition from foraging to farming. It had ratcheted up the human species, and everything associated with it.

Farming provided assured food security and leisure. It led to creative thinking, culture, arts and science, music, philosophy, religion, etc. Several civilizations rose (ratchet) and fell (hatchet) largely due to environmental degradation and socio-political conflicts. During the past several millennia, the human civilizations were spatially and temporally separated. There was no globalization that promotes uniformity (a kind of monoculture) than unity in diversity. Globalization reduces the diversity which is essential for adaptation and resilience.

The last three millennia of history of *H. sapiens* has been replete with several cycles of ratchets, hatchets and pivots. The invention of steam engine in 1780 by James Watt ushered in an era of Industrial Revolution. Advances in physics, particularly nuclear physics and chemistry in the 19th century greatly impacted the human civilizations and the environment. These provided uncommon opportunities to 'twist' nature in order to develop 'pivots' to ratchet up the human species in association with cultural ethos. However, it is not uncommon that a pivot of today becomes a hatchet of tomorrow. The author does not allude to this fact explicitly, but references in the book to the Haber–Bosch process to chemically fix the atmospheric nitrogen as ammonia and the indiscriminate use of dichloro-diphenyl-trichloroethane (DDT) and other chemical pesticides are suggestive