REVIEWS

The Universe in a Box: A New Cosmic History, by Andrew Pontzen (Vintage), 2024 (first published 2023). Pp. 251, 19·8 × 13·8 cm. Price £12·99 (paperback; ISBN 978 1 529 92200 4).

Andrew Pontzen, until recently a professor of cosmology at University College London, is now a professor at the University of Durham. While this is his first book, he has popularized science in magazines, on radio, and on television, and is well known in the field of cosmological simulations, the topic of this book. A good move is to start with discussing weather and climate, something people are familiar with; the distinction between the two (details at a particular place and time as opposed to long-term large-scale trends) carries over into cosmological simulations, where the goal is to understand the general behaviour, not to mimic a specific scenario in detail. There are many interesting historical details on weather forecasting, climate simulations, chaos, and so on. The second chapter has a similar discussion with respect to simulations of the large-scale structure of the Universe and the roles of dark matter and dark energy in producing structures such as the cosmic web. History is important here as well and I was happy to meet Erik Holmberg's fascinating optical analogue computer for galaxy simulations for the second time in a popular-science book (for the first, see refs. 1 & 2). Like the details of raindrops or even clouds in weather simulations, individual stars are much too small to be resolved in a cosmological simulation, leading to a discussion of sub-grid approximations, heuristic parameterizations designed to accommodate such small-scale phenomena into the simulation. An important application is the introduction of baryonic physics to refine more straightforward simulations containing only dark matter and dark energy. There is a balanced discussion between the critical claim that one gets out only what one puts in and the increased faith in such schemes when they successfully predict behaviour for which they were not designed. In that respect and others there is good discussion of how one uses simulations as a tool for understanding rather than to mimic reality. An important sub-grid phenomenon in galaxy simulations are black holes and their effects on star formation, worth an entire chapter.

Chapter 5 shifts gears somewhat by moving to quantum theory, but that is relevant due to the role played by quantum mechanics in the early Universe and its potential role in quantum computation. Computation is the subject of the sixth chapter on machine learning in general and its uses in astronomy. While rightly criticizing current exaggerated hype ("ChatGPT ... comes across as a bland know-it-all" with its output being "like a mediocre TV script: believable on the surface but with little substance" with aimlessly drifting conversations lacking any large-scale coherence and limited to "the restatement of existing ideas that it found who-knows-where on the Internet")*, Pontzen also considers it a realistic possibility that artificial intelligence could improve enormously and emulate or exceed human thinking in many respects. That leads to a discussion of the simulation hypothesis, the idea that if consciousness is easy enough to simulate, then a typical conscious being is more likely to be simulated than real[3]. The idea has prominent supporters — or at least some who don't think that it is patently absurd and not worth considering — (including the Astronomer Royal[4]), but also prominent detractors (such as George Ellis, who reminded

*On the other hand, a good friend of mine once described conversations between his fellow pupils at school as the mutual exchange of standard statements they had learned by heart; he is now a teacher.

the audience of his view on that topic at a recent philosophy-of-cosmology conference I attended in Milan). Pontzen speculates that such a simulation might employ sub-grid methods, as one would need the entire Universe to simulate the Universe in detail (though if our Universe is simulated, we don't know anything about the universe in which that simulation is running). (However, if simulating consciousness is a goal (and one could argue that simulated consciousness is also consciousness), I wonder why the much easier task of simulating a brain and its sensory inputs is not a more popular topic.) In the same, final, chapter is an over-arching discussion of 'Simulations, science and reality' which also serves as a summary of the book.

This is not a book about the details of simulations[†] but about their purpose, their role within science, even the human side of them, presenting a balanced view by an expert on the subject. Thirteen pages of small-print endnotes sometimes play the role of footnotes but are mostly references, usually to the scientific literature but also to various internet resources. An eleven-page small-print index ends the book. There are no figures. It is well written with a lower than average number of typos and so on. My only real complaint is a paragraph which, while also recognizing his contributions, is strongly critical of Feynman as a person; even if true, I don't see the relevance to the rest of the book nor any reason why Feynman is singled out for such criticism. Apart from that, I can warmly recommend the book. — PHILLIP HELBIG.

References

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(4) M. J. Rees, https://www.edge.org/documents/archive/edge116.html
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(6) S. Phillipps, *The Observatory*, **144**, 37, 2024.

Steven Weinberg: A Life in Physics, by Steven Weinberg (Cambridge University Press), 2025. Pp. 253, 23·5 × 16 cm. Price £25/$29·95 (hardbound; ISBN 978 1 009 51347 0).

Steven Weinberg's (1933–2021) autobiography will become an invaluable source for future historians of physics and astronomy. His candid memoir of a scintillating life in physics opens with a child's memory of the key books that sparked his innate curiosity about the physical world. George Gamow's creation, Mr. Tompkins, introduced young Steven to the weird world of Special Relativity and quantum mechanics; science-fiction classics likewise stirred his imagination; and from Jeans' *The Mysterious Universe* he gleaned that he "would need special mathematics" to make sense of the universe. 'Making sense' became Weinberg's lifetime goal.

Weinberg was polishing his memoirs at the time of his death. Steven's wife, Louise, has organized and edited them to produce this engaging account of his life as a scientist and public intellectual. Many vignettes of his formative encounters with dozens of leading physicists in the mid-20th Century enrich the narrative. Weinberg's talent as a writer of popular science shines through brightly. He offers many good stories: on working styles, he liked to work on fundamental physics with the TV tuned to the History Channel, a trick that doubled his productivity — absorbing some old knowledge while striving to

[†]Those interested in that aspect might want to consult a book[5] reviewed last year in these pages[6].

make sense of new knowledge. Louise and Steven passionately shared their life experiences as academics in search of truth. Each had a study as a place for quiet work at home. Steven recounts (page 112) that he became habituated at working from his desk overlooking the garden. We are in the time of the Vietnam war, when Steven spent his time on informed interest in international affairs, trying to make sense of the new world order. Louise steered him away from the dismal company of disheartened older men and directed her young husband to get back to working on physics. Steven writes: "I do not exaggerate when I confess that she saved my life", a great life in physics no less. Weinberg's prose style is redolent of Émile Zola's novelistic realism, which blends rather well with the racy travelogue approach of Gamow's *My World Line* (Viking, 1970). Weinberg is instructive on how one should write history of science in a contemporary style, composed of social contexts, complex conundrums, and conflicting conclusions. Echoing Copernicus (1543), I recommend diligent readers "to buy, read, and enjoy this work." — Simon Mitton.

The Known Unknowns: The Unsolved Mysteries of the Cosmos, by Lawrence M. Krauss (Head of Zeus), 2024 (originally published in 2023). Pp. 373, 20 × 13 cm. Price £9·99 (paperback; ISBN 9781801100656).

Lawrence Krauss has worked at various US universities in several fields related to cosmology and particle physics (including strong gravitational lensing, so his papers on that topic crossed my desk back at the beginning of my career — yes, real papers and a proper antique desk back then) and has written around a dozen popular-science books (of which so far, apart from this book, I've read only his biography of Richard Feynman). The title refers to a famous quotation by former US Vice President Dick Cheney, which follows one by Feynman in which he notes that he isn't frightened by not knowing things.

Space, time, matter, life, and consciousness. Those are the topics explored in the corresponding five chapters. While the known unknowns are mentioned, most of the text is a presentation of what we do know. Of course, 36–60 pages per topic is not anywhere near enough to give a complete overview; rather, there is a very broad-brush summary and a few topics are discussed in somewhat more detail. Readers familiar with a topic will thus probably find little that is new, and even the known unknowns might be familiar. Each chapter begins with a list of a handful of questions, the answers to which are always 'We don't know.' One example from each chapter: 'Does time have a beginning?', 'Are there hidden dimensions?', 'Will matter end?', 'Is DNA life unique?', 'Can we create [consciousness]?' While those questions are discussed in the corresponding chapters, they are not a table of contents: the order isn't always the same, and they arise in the context of discussion of more specific topics.

There are some good discussions, such as the relationship between the geometry and destiny of the Universe and how that is affected by the presence of a cosmological constant or some more bizarre form of dark energy, a topic often presented wrongly. The book is well written and a good mixture of the current consensus on various topics and the author's own opinions. I learned a few things, such as the puzzle of conflicting measurements (depending on the method) of the half-life of the neutron. However, I'm struggling to find the target readership. Those familiar with the topics will already know the known unknowns. Those who aren't can't get an impression of how they relate to the rest of the corresponding field from the information provided here. (Having said that, discussion of a few topics in a bit more detail avoids repeating broader but shallower capsule summaries of entire fields.) They could also be led astray by statements such as that dark energy causes the Universe to expand, or an unfortunate typo (resulting in an essentially opposite statement) in the otherwise good discussion of why the net electric charge in a spatially closed universe must be zero. Most readers of this *Magazine* will probably be more familiar with the first three chapters than the last two and might very well learn more from them, but by the same token it would be difficult to appreciate Krauss's description of the known unknowns if they don't know the known knowns.

There are no figures and neither footnotes nor endnotes. The seventeen-page index is quite thorough for a book such as this one, though unusually not set in a smaller font than the main text. Despite my qualms, this is not a bad book by any means, but one of those which the potential reader should browse personally first (as indeed I had done before I bought it) in order to decide whether it is worth reading. — PHILLIP HELBIG.

Amazing Worlds of Science Fiction and Science Fact, by Keith Cooper (Reaktion), 2025. Pp. 248, 21·5 × 14 cm. Price £15 (hardbound; ISBN 978 1 78914 994 4).

Planetary science and Science Fiction (SF) were always closely related. Well before *Sputnik* in 1957, some of SF's earliest writers (*e.g.*, Verne and Wells) and indeed hugely influential, 1950s-based ones (*e.g.*, Asimov, Clarke, and Heinlein) often looked up at the (mainly) night sky and postulated. Here, Keith Cooper (*Astronomy Now*'s editor) brings these two areas back into focus. Within SF, barren, dry Tatooine (*Star Wars*), spice-laden Arrakis (*Dune*), and icy Gethen (*Left Hand of Darkness*) are themselves spectacular but there are real, strange exoplanets out there (*e.g.*, the Trappist-1 system, Proxima b, Kepler 16b, and LHS 1140b).

Earlier SF lacked much of the data we now have but many current writers use up-to-date information in formulating their scenarios. This is not only due to the marvellous 2·4-m *Hubble* but also because of its more recent and powerful 6·5-m upstart — the *JWST* (both outside our protective atmosphere). The book's appendix lists a number of SF scribes consulted and also has a column (nice!) of major SF novels, films, and TV (all referenced therein).

The cover and book title 'nods' to *Amazing Stories* — a US-based 1950s 'pulp', comic-like paperback publication. Carrying many now classic SF short stories, it was often taken to the UK (as ship's ballast). Cooper also deals herein with the Earth Similarity Index — our own planet being of course 1·00. The nearest to us in said Index — Teegarden's Star — has 0·95, though that exoplanet is not at all like ours in many ways. And so far, we appear to be alone.

Cooper also deals with biosignatures (phosphine and dimethyl sulphide) — strong signatories of possible life elsewhere. And our own Solar System has prime candidates: not only Jupiter's Ganymede, Callisto, and (*vide* Clarke's *2010* novel/movie) Europa, but also Saturn's Enceladus. And all amino acids linked to life are left-handed whereas sugars are right-handed. The text here ranges over many other scientific items (including Roche limits, magnetic pulsars, extratrojans, ecumenpolises, and Dyson spheres).

Cooper's book contains a lot of data but no mathematical formulae. And it is nice when he uses such terms as 'astronomical unit' or 'parsec' and then defines them. This tome appears to be targeted at SF readers and those (non-professional astronomers) who enjoy popular science. However, many in the astronomy field will also enjoy this. I certainly did. Recommended. — DAVID LALLY.

The Life and Work of James Bradley: The New Foundations of 18th Century Astronomy, by John Fisher (Oxford University Press), 2023. Pp. 531, 24 × 16 cm. Price £ 83 (hardbound; ISBN 978 0 19 888420 0).

James Bradley was the third Astronomer Royal, following John Flamsteed and Edmond Halley but, despite his achievements — including discovery of aberration and nutation — and widespread recognition in his own life-time, is not as well known today. In comparison with his predecessors, he has been neglected by biographers, so this comprehensive biography by John Fisher is very welcome. His *Life and Work of James Bradley* is embedded in context: astronomical and social, especially networking and patronage. It was an exciting time for astronomy: Rømer had shown that the speed of light was finite, but annual parallaxes in confirmation of the heliocentric system had yet to be convincingly demonstrated. In Chapter 1, Fisher covers the work and tribulations of Flamsteed, as a comparison and contrast with Bradley. Bradley's own introduction to astronomy was *via* his maternal uncle, James Pound, who took him under his wing. Pound's influence on Bradley's career was so significant that Chapter 2 is devoted to his activities prior to taking on his nephew. Pound had entered the service of the English East India Company as a chaplain and had, over a few years, sailed between various company stations in the South China Sea. He was also a skilled astronomer and was provided with a quadrant by Flamsteed to make observations for him. At some time in 1702–03, Pound was posted to the island settlement of Pulo Condore, close to the mouth of the Mekong Delta. There he took up residence in a wooden dwelling situated about 400 yards outside the fortified settlement — which was fortuitous because this saved his life during the massacre which took place in the settlement on the night of 1705 March 3. According to Fisher, the best account of the massacre is that given by Pound in his letter to the Court of Managers of the Company. Along with 14 others, he escaped on a sloop and after a harrowing voyage reached Batavia. Pound returned to England in 1706 July and a year later was offered the lucrative living of Wanstead, near London.

In 1711, James Bradley took up residence with Pound and entered Oxford University in preparation for a career in the Church of England, as desired by his father. He also began assisting Pound in his astronomical observations. From examination of the Wanstead observing books, Fisher shows that Bradley's first recorded observation in 1715 indicated that he had by then become a very capable observer. Bradley's day-to-day observing record is included in the detailed, often day-by-day, chronology of his life and work presented in Appendix 1. This chronology includes a great deal more information, making it a valuable resource. Many of the observations were of the Galilean satellites of Jupiter on behalf of Halley, who had become his mentor. Bradley was eventually given the credit for the observations when they were published by Bevis in 1752, but we are not given a reference for this. Nor is a reference given for the tables for Jupiter's satellites published by Hodgson in 1749 which "studiously avoided all mention of Bradley" (p. 94). This is unfortunate. It would have been interesting to read — or find out using the references — how the observations compared. Fisher returns briefly to the satellites on pp. 150–151, reporting Bradley's recognition that the three inner satellites were interacting gravitationally with one another, effectively laying the ground for the Laplace Resonances. I would like to have read more about this. Halley had hoped to use timing of the Galilean satellite eclipses to solve the longitude problem but such observations were impractical from the deck of a ship at sea. On the other hand, Bradley was able to use them to determine the longitudes of Lisbon and the fort of New York relative to London.

For the first half of 1719, Bradley continued observing vigorously; but then he was ordained and received a living at Bridstow. Through the efforts of Samuel Montagu, private secretary to the Prince of Wales, he also received half a divided living in Pembrokeshire in 1720. Fisher reports that Pound laid out over £18 in fees in connection with the latter. As he took up his duties, Bradley's observing ceased — but not for long. In 1721 he was elected to the Savilian Chair of Astronomy at Oxford. It had been initially offered to Pound, who declined it because holders of the chair were not allowed to hold ecclesiastical benefice, with the consequence that he would have to give up his livings. Once Pound had declined, Bradley's candidature was supported by Lord Chancellor Thomas Parker, and Pound paid the costs of the election. Bradley's church sinecures were sufficiently modest that giving them up was an acceptable sacrifice.

Bradley's observations leading to his discovery of aberration and nutation began in a campaign led by Molyneux at his house at Kew, where he had installed a zenith sector built by George Graham. The aim was to repeat Hooke's experiment of 1669 from which he claimed to have measured the parallax of γ Draconis. Bradley's observations of this star showed movement, but not in the sense expected of annual parallax. Fisher brings out well the progress of the experiment, and the consideration of alternative explanations. To test the possibility that they were observing nutation, Bradley and Molyneux began observing another bright star separated by 12 hours in right ascension, whose movement soon enabled them to rule out that possibility. To increase the number of stars observable, Bradley commissioned from Graham a new zenith sector having a larger field of view. After Pound's death, Bradley no longer had access to the Wanstead parsonage but was able to continue observing from the nearby house belonging to Elizabeth Pound, his aunt. The new sector was installed there and Bradley was able to measure motions of stars having a range of right ascension. In April 1728, a pattern became apparent: the stars' motions ceased when they were observed at times when the Earth was moving directly towards or away from them. Later that year, he deduced the cause in terms of the Earth's motion in its orbit round the Sun and the finite velocity of the light from the stars — a new, unexpected phenomenon that confirmed the heliocentric view. Fisher sets out Bradley's argument in full. There are three versions of his report written in letters to Halley: Fisher identifies Bradley's 'final' version and presents this in Appendix 2, together with the differences between it and the version read by Halley to the Royal Society and published in the *Philosophical Transactions*.

In 1729, Bradley accepted the post of lecturer in experimental philosophy at Oxford for which he delivered two or three courses of 20 lectures a year for over 30 years. This lay outside the duties associated with the Savilian Chair and provided valuable additional income. His principle was that the laws of nature could be discovered only "by experiments and observation & examining the Phaenomena & finding from them by what laws their motions are ordered and regulated which is properly the Business and scope of Natural and Experimental Philosophy". Bradley's course notes are not available, but the author gives us (in Chapter 6) an account of the content from the note book of one of the students. In 1732, the increased demands on his time in Oxford prompted him to move from Wanstead to the Oxford dwelling that came with the Savilian chair. His aunt Elizabeth Pound accompanied him to Oxford, but he was able to continue observing with the zenith sector at her house in Wanstead. This he did until 1747, when he completed his investigation of the residuals from his observations of aberration suggesting the existence of another, distinct phenomenon. This was the nutation of the Earth's axis caused by the Moon. Bradley had suspected this early in his study but continued observing to cover a whole period, 18·6 y., of the precession of the Moon's orbital nodes — not only was he a meticulous observer, but also a very patient one, willing to continue a campaign long enough to make certain of a result. Besides these and many other observations (Appendix 1), and his teaching, he was active in other projects: studying the shape of the Earth from isochronal pendulum observations in collaboration with Graham, helping the Earl of Macclesfield set up his well-equipped observatory in Shirburn Castle, and beginning his tenure at the Royal Observatory.

Bradley was appointed Astronomer Royal on the death of Halley in 1742. Fisher gives an illuminating picture of the networking behind this appointment. Bradley's earliest years at Greenwich were taken up with testing and rectifying the instrumentation, which had been neglected during the final years of Halley's life, often with the aid of observations made at Shirburn Castle. In 1749 he requested funding to remedy the dire state of the instruments and facilities at the observatory. This was supported by the Board of Visitors, Royal Society, and Admiralty with the result that George II agreed an award of £1000. He constructed the New Observatory (Transit House) building to house the quadrants and new transit instrument. The prime meridian defined by the latter became the origin for the Ordnance Survey. In 1750, he began observations for a Catalogue of 3222 stars, each star being observed 20–30 times, together with ancillary data including atmospheric pressure and temperature to allow correction for refraction. He was not satisfied with possible treatments of atmospheric refraction and the data remained unreduced.

Any biographer of Bradley has to contend with the fact that, after his death, all of his Greenwich observations (shades of Flamsteed!), correspondence, and other items passed to the executors of his estate. Fisher gives a good account of the long battle with the Board of Longitude for the papers followed by their subsequent poor handling by Bradley's successor at Oxford, Thomas Hornsby, with the result that some were lost. Eventually, Bradley's comprehensive observations for his Catalogue of 3222 stars were reduced by Bessel and published only in 1818.

This is a substantial work, based on abundant primary sources with endnotes to each chapter. Some of the references are not easy to decipher owing to the misuse of the abbreviation '*ibid*' where there is no connection with the immediately preceding references. Altogether, the book would have benefitted from the help of an editor, who could also have removed some of the repetition and re-ordered some of the material to improve the flow. That being said, the author has successfully restored Bradley to his rightful place with the fullest ever account of his scientific life and legacy. Along the way, we can learn much about the practice of astronomy at the time, giving another reason to recommend this book heartily. — PEREDUR WILLIAMS.

Power Laws in Astrophysics. Self-Organized Criticality Systems, by Markus Aschwanden (Cambridge University Press), 2025. Pp. 264, 25 × 18 cm. Price £125/$160 (hardbound; ISBN 978 1 009 56293 5).

The concept of self-organized criticality was introduced only in the late 1980s but its validity covers an enormous range of physical phenomena. One of the most familiar is the 'sandpit' model in which avalanches occur according to some instability. The result is often power laws in size distributions. This book is a very detailed discussion of the concepts of power laws in astrophysics with comparison to observations both from space and ground-based. In the realm of solar physics, which is the main expertise of the author, power laws in size distributions are extremely common and are particularly well illustrated in this book. For those not especially familiar with self-organized criticality, possibly a more general introduction to the subject might profitably be read in combination with this specialized monograph. — KEN PHILLIPS.

A Brief History of Black Holes: And Why Nearly Everything You Thought You Know About Them is Wrong, by Dr. Becky Smethurst (Pan Books), 2023 (originally published 2022). Pp. 290, 19·7 × 13 cm. Price £10·99 (paperback; ISBN 978 1 5290 8674 4).

According to the back-cover blurb, Smethurst is YouTube's most popular astrophysicist. With an impressive list of awards, she is also an RAS Research Fellow at the University of Oxford, focussing on the interaction of supermassive black holes and galaxy evolution. In contrast to the next book I read[1,2], this is very much a book about astrophysics and the roles black holes play in it. The scope is broad and starts with background, both physical and historical, about stellar structure and evolution and General Relativity (GR) before coming to black holes themselves (some pre-GR ideas about black holes are briefly mentioned). Throughout the book, the history of the topic is well entwined with the astrophysics being discussed, an organic whole rather than a straight history of science about a topic which is still relevant or a book on astrophysics with historical footnotes. Traditional (non-quantum) black holes and other compact stellar remnants set the stage for more concrete astrophysics (the chapter on why black holes are not black is not about Hawking radiation, but about X-ray astronomy). Black-hole mergers and their detection *via* gravitational waves, the possibility that Planet 9 is a black hole, supermassive black holes, accretion discs, and the role of black holes in galaxy evolution are among the topics in the fifteen relatively short chapters. The final chapters deal more with the mathematical theory of black holes and Hawking radiation, though like the rest of the book in a non-technical manner.

The book is well written in an entertaining style and is a good non-technical introduction to the importance of black holes in astrophysics. Since her research is also on that topic, I feel safe in recommending it. I enjoyed reading it except for the very end. The book only briefly discusses the CMB, but I found it strange that while *WMAP* is mentioned, *Planck* is not. Although they make up only a small part of the book, the final pages discussing cosmology contain several mistakes. First, the density parameter is explicitly defined to include matter, radiation, and dark energy, but is followed by an almost standard textbook discussion for the case of no dark energy. But even that is not correct, because the description of eternal (asymptotically exponential in the case of a positive cosmological constant) expansion is conflated with the idea of the Big Rip, in which even (gravitationally or otherwise) bound objects will be torn apart, though that could happen only with a non-standard, highly speculative form of dark energy. If, as explicitly stated, the cosmological constant is not assumed to be zero, then the relation between geometry and destiny, *i.e.*, between spatial curvature and the future expansion (or contraction) of the Universe, is much more complicated. However, again the textbook version with no cosmological constant is presented. While it is correctly stated that *WMAP* measured the Universe to be at least very nearly spatially flat, that is characterized as being on the border between Big Rip and Big Crunch; in fact, there is no uncertainty at all in the concordance model of cosmology that the Universe will expand forever (unless something unknown has not been taken into account, but that would go beyond the concordance model); geometry and destiny are not so simply related. Those are not fine technical details but rather the most basic ideas in cosmology, so I find it rather strange that those and other basic misconceptions are also found within other popular-science books written by people who obviously know more than enough people who could have critically read the manuscript (*e.g.*, refs. 3,4). (There are a few other things a proof reader should have caught: Kirchhoff always has one 'h' too few and Secchi sometimes one too many; Rutherford won a Nobel Prize, but for chemistry, not physics.)

There are a few black-and-white figures scattered throughout the book. The brief bibliography contains twelve references, but it is not clear why those twelve (which are not mentioned explicitly in the text). One hundred and sixteen footnotes (easy to count since numbering doesn't restart with each chapter) will appeal to those who, like myself, like footnotes (especially when compared with endnotes). A twelve-page small-print index ends the book. The book does what it sets out to do well, but shouldn't have included the few pages on cosmology at all; even if they were correct, they don't really belong in a book about the astrophysics of black holes, so I can recommend it if the last chapter is skipped. — Phillip Helbig.

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Annual Review of Earth and Planetary Sciences, Vol 52, 2024, edited by R. Jeanloz & K. H. Freeman (Annual Reviews), 2024. Pp. 692, 24 × 19·5 cm. Price \$529 (for institutions; about £420) \$126 (for personal copies; about £100) (hardbound; ISBN 978 0 8243 2052 2).

The latest volume of *Annual Review* covers a nice diversity of subjects that includes the biosphere, mantle composition and dynamics, the atmosphere, and the hydrosphere. An old Icelandic saying is that a good story should start with an earthquake and then build up to a climax. This year's volume seems to have paid attention to this, and starts with chapters on volcanism in Hawai'i and aftershock forecasting. Highly recommended. A chapter on microbial life brings home the message that this is the foundation, both in longevity and mass, of life on Earth. Microbial life is not just the icing on the cake. The development of this is covered by a following chapter on early Paleozoic evolution and the door is then closed by a chapter on the Pleistocene extinction. The interior of Earth is discussed in a variety of chapters on halogen cycling, diamonds, lithosphere, and mantle rheology. As regards the deeper mantle, despite all our work it seems still unclear whether it has a similar composition to the upper mantle (and thus convects as one with it) or not. Differences of up to 10% seem possible. Climate is represented by chapters on the stability of ice shelves and past hothouse climates. A chapter on carbon-climate feedbacks directly addresses the implications of the Paris Agreement. The situation is challenging, even if the main goal is met, which itself seems improbable. Uncertainties are large, but one thing we can confidently say is that natural carbon sinks will become less efficient with time. An interesting chapter deals with that part of deep groundwater that is locked in the lithosphere. For river-running enthusiasts, a chapter deals with the hydrotectonics of Grand Canyon groundwater, which presents a rare chance to monitor vertical water movement without the use of boreholes. Check out the book and find out what the Indonesian Gateway is! The volume finishes with an unusual chapter on the relationship between grain size and landscape. So if you feel like a bit of a change, then start reading the book from the back. — Gillian R. Foulger.

The Cosmic Microwave Background: Historical and Philosophical Lessons, by Slobodan Perović & Milan M. Circović (Cambridge University Press), 2024. Pp. 215, 25 × 17·5 cm. Price £39·99/$49·99 (hardbound; ISBN 978 1 108 84460 4).

As the subtitle states, this is a book on the history and philosophy of the CMB. However, it does not stray far from actual physics, and points are made with the help of concrete examples. The second author is someone I've often encountered in the history-and-or-philosophy-of-science literature, and the authors have a good grasp both of that and of astrophysics. The conventional narrative is that the CMB suddenly proved that the Steady State cosmological model was inviable. While the CMB is expected in the Big Bang scenario, it is not impossible in the Steady State theory, which is based on the idea that on a large-enough scale, the Universe looks the same at all places and at all times. Nevertheless, one would still like to have an astrophysical explanation for the CMB within the Steady State theory. For Fred Hoyle, one of the main motivations for the Steady State cosmology was that it in principle made all processes accessible to scientific inquiry, which might not be true of the Big Bang itself. However, counts of radio sources ruled out the Steady State model. Both supporters of the Steady State model and those of Big Bang cosmology investigated alternative explanations for the CMB, and it was not until features in the power spectrum were discovered about 25 years ago that the scales were finally definitively tipped in favour of a Big Bang origin for the CMB. That is not only an interesting story in itself, but also such dead ends are important because they illustrate how the scientific process actually works.

The thirty-one chapters are clearly structured into seven parts covering the basics of cosmology, the Big Bang, and ΛCDM (referred to, unusually, as λCDM); discovery of the CMB and the current standard model, but including a discussion of shortcomings in usual potted histories; the nature of (un)orthodoxy in cosmology; moderate unorthodoxies (CMB with Big Bang); radical unorthodoxies (CMB without Big Bang); the history of how the current orthodoxy came to be; anomalies in the CMB and wider issues such as the Anthropic Principle, boundary conditions in cosmology, and the Multiverse, using the CMB as a jumping-off point. Too long to quote here, the end of Chapter 9 ('Was the CMB a smoking gun?') is a good summary of the strategy of the book: a balance between questioning a too-streamlined view of history without questioning the state at which that history has (probably correctly) arrived; learning from blind alleys and misconceptions, some of which later proved useful in other contexts; and a good balance between astrophysics and philosophy by authors knowledgeable about both topics. To some extent, this book reminded me of a similar book with much broader scope[1] reviewed in these pages[2], though I found that the latter was sometimes a bit too broad and too forgiving. (At the same time, that book is conspicuous by its absence in the otherwise thorough sixteen-page reference list in somewhat smaller print, though two of his articles, one on essentially the same topic as his book, are cited.) An interesting idea is adapting the idea of biological exaptation to cosmology: features originally developed for one purpose are later put to another use (*e.g.*, feathers for heat regulation being used as components of wings for flying); similarly, ideas which were mistaken at the time might later prove useful in other contexts. The authors also use the history of CMB research to point out the "abject failure of simplistic social-constructivist notions about the sociocultural determination of the *content* of scientific theories" and the more 'mature' culture of debate compared to some previous controversies, avoiding "juicy tabloid details like the personal relationship of actors such as Hoyle and Ryle".

At best confusing is the two-page Chapter 28 which briefly sketches ideas about two (initially) puzzling phenomena: 'fingers of God' in the distribution of galaxies and the 'axis of evil' regarding the alignment of CMB multipoles. While the summaries are fine, the authors don't point out that the former is now understood (peculiar velocities of galaxies introduce redshift-space distortions so that the true shapes appear distorted when plotted in redshift space as opposed to distance), while the latter — on which the jury is still out but might be something genuinely interesting — is toned down by (correctly) suggesting some possible banal explanations. Otherwise, my only real complaint is that some citations in the text are not in the reference list; in some cases there are obvious mistakes (the year is off by one, for example), but in others (one of which is cited often) they appear genuinely to be missing. (I always wonder why authors do not use BibTeX or some other scheme to automate references, at least when not writing a book review for *The Observatory*.)

There are a few black-and-white figures scattered throughout the text. Eight pages of small-print endnotes follow the main text (which includes two appendices on relativistic cosmological models and dipole anisotropy). A four-page small-print index follows the reference list. Despite neither author being a native speaker of English (as far as I know), the language is good and both typos and questionable choices of style are few. The emphasis is on what the CMB can tell us about how science is (and has been) done rather than on the physics of the CMB itself, a basic knowledge of which is assumed. It is thus a good book for those with such knowledge who want to learn more about the history and philosophy of the field in the context of a concrete example. I've recently attended several conferences on the history and philosophy of science* and am often surprised about how well the participants are familiar with scientific details (though it is true that many were trained as scientists then switched to history and/or philosophy). Despite Feynman's claim that the philosophy of physics is as useless to physicists as ornithology is to birds, I think that it would be good if more working physicists were familiar with the history and philosophy of their field, both for its own sake and for the benefit it can bring to actual science; this book is a good starting point. — PHILLIP HELBIG.

References

(1) M. López-Corredoira, *Fundamental Ideas in Cosmology: Scientific, philosophical and sociological critical perspectives* (IoP Publishing), 2022.
(2) P. Helbig, *The Observatory*, **143**, 214, 2023.

*I'm writing this in 2025 January, a few days before a workshop on the philosophy of dark energy. Of nine conferences I attended last year, seven were on the history and/or philosophy of science (usually physics, here usually astrophysics, and there usually cosmology); among others were workshops on the philosophy of inflation and the philosophy of black holes. As a joke I asked a fellow participant when we could expect one on the philosophy of radio interferometry, but interestingly he didn't take it as a joke at all. (Interestingly, several of those conferences were co-organized by one of the two back-cover-blurb writers.)

Archimedes. Fulcrum of Science, by Nicholas Nicastro (Reaktion), 2024. Pp. 191, 22·5 × 14·5 cm. Price £15·99 (hardbound; ISBN 978 1 78914 922 7).

This biography of Archimedes of Syracuse (modern Siracusa, Sicily), the greatest mathematician in the ancient world, is a fine example of modern historiography. Its accounts of context, circumstance, and consequence combine to portray such a vivid tableau that you can imagine you're standing in the shadow of this remarkable polymath: engineer, inventor of engines of war, and pioneer of geometry. Over 1800 years elapsed before the next great mathematician walked on the stage, Isaac Newton, who praised Archimedes as one of the giants on whose shoulders he had stood. Historians have only meagre sources on the life of Archimedes. In his *Life of Marcellus*, Plutarch documents the defensive devices that Archimedes deployed while protecting Syracuse against the Romans' assault from the sea. Plutarch also lamented the death of Archimedes, killed by a Roman soldier. In one version of the story Plutarch adds celestial colour by noting that Archimedes was carrying mathematical instruments such as sundials, spheres, and quadrants. Recent scholarship adds the name of Archimedes to the story of the Antikythera Mechanism, an ancient analogue device recovered in 1901 from a shipwreck that allowed the user to simulate the motions of the Sun, Moon, and the five planets known to the ancients. With the expected restraint of an accomplished historian, Nicholas Nicastro airs the notion that "Archimedes' work on sphere-making *inspired* the calculating devices that followed."

What impressed me most about this title is the delightful manner in which it rises above familiar and well-worn recitals of myths, legends, and traditions by focussing on what we really do know about everyday life and the academic pursuit of knowledge in Syracuse in the third century BCE. The author offers a pretty good example of an accessible public history rather than a dull chronicle. Read and enjoy! — Simon Mitton.

Black Holes: The Key to Understanding the Universe, by Brian Cox and Jeff Forshaw (William Collins), 2023 (originally published 2022). Pp. 288, 19·7 × 13 cm. Price £19·99 (paperback; ISBN 978 0 00 839064 8).

There are of course many popular-science books on black holes, at a variety of levels and with a variety of emphases, such as the book I read just before this one[1,2]. However, the two books are very different. This book is about the mathematical theory of black holes. There is little material on astrophysics and that is only to understand the formation of astrophysical black holes. Both authors are professors of theoretical particle physics at the University of Manchester; Cox is well known as a popularizer and is also the Royal Society Professor for Public Engagement in Science. Those who take the trouble to understand a topic outside of their own field are usually good at explaining it, as I've noticed in other books (*e.g.*, refs. 3,4); that is certainly the case here. While there are only a few equations, there are several diagrams, many of them Penrose diagrams. This is the book if you want a thorough, correct, yet mostly non-mathematical introduction to Kruskal–Szekeres coordinates and want to have fun in the process.

After a brief history of black holes, the necessary background is built up piece by piece: Special Relativity, General Relativity (GR), Penrose diagrams, curvature, the interior of black holes, white holes and wormholes, and rotating (Kerr) black holes. Only after that do we meet collapsing stars, and then mainly to understand where many black holes come from. After that, the emphasis shifts to topics of current research: black-hole thermodynamics; Hawking radiation; the fate of objects before, during, and after crossing the event horizon; quantum entanglement; the holographic principle; AdS/CFT correspondence; and the connection between the previous two topics and quantum information. All are rather technical topics in the mathematical theory of black holes, yet the descriptions are both correct and easy to understand, with little mathematics. As such, this book is a very good introduction to those like myself who like a 'physics first' approach to GR: first understand the concepts then learn as much maths as necessary to work with them. While the entire book is good, I made a note of the fact that the chapters on white holes, wormholes, and Kerr black holes are particularly good. The only mistake I noticed is the old canard that John Wheeler coined the term 'black hole' (something Smethurst[1] gets right and which she discusses in some detail).

As almost always I notice a few matters of style which depart from my own preferences, but less so than in most books. There are many black-and-white figures, mostly space–time diagrams, scattered throughout the book, some of which also exist on the sixteen traditional glossy colour plates at the middle of the book. The four pages of endnotes are references to the technical literature (footnotes are proper footnotes). An eight-page small-print index ends the book. This is the best non-technical detailed introduction to the mathematical theory of black holes, a judgement which would probably stand even if there were others.

Recommended. — Phillip Helbig.

References

(1) B. Smethurst, *A Brief History of Black Holes: And Why Nearly Everything You Thought You Know About Them is Wrong* (Pan Books), 2023.
(2) P. Helbig, *The Observatory*, **145**, 125, 2025.
(3) W. D. Heacox, *The Expanding Universe: A Primer on Relativistic Cosmology* (Cambridge University Press), 2015.
(4) P. Helbig, *The Observatory*, **136**, 204, 2016.

Other Books Received

The Physics of Supernovae and Their Mathematical Models, by Alexey G. Aksenov & Valery M. Chechetkin (World Scientific), 2024. Pp. 279, 23·5 × 16 cm. Price £100 (hardbound; ISBN 978 981 12 8509 7).

A theoretical, and highly mathematical, monograph on supernovae, covering basic principles, numerical methods, and applications.

Introduction to Supergravity and Its Applications, by Horatiu Nastase (Cambridge University Press), 2024. Pp. 426, 26 × 18·5 cm. Price £64·99/$84·99 (hardbound; ISBN 978 1 009 44559 7).

Aimed at PhD students, this volume covers the basic formalism of supergravity suitable for a focussed first course.