(8) M. Chown, *A Crack in Everything: How Black Holes Came in from the Cold and Took Cosmic Centre Stage* (Head of Zeus), 2024.
(9) P. Helbig, *The Observatory*, **145**, 216, 2025.

The Arrow of Time: From Local Systems to the Whole Universe, edited by Cristian López & Olimpia Lombardi (Cambridge University Press), 2025. Pp. 315, 17 × 26 cm. Price £130 (hardbound; ISBN 978 1 00958 157 8).

There are many arrows of time (as "time's arrow" a term coined by Eddington): cosmological, thermodynamic, electromagnetic, quantum-mechanical, causal, weak-interaction, *etc*. When I was a student at the Hamburg Observatory, in the excellent library I found and read a book on *The Nature of Time*[1], the proceedings of a meeting held at Cornell in 1963, convened by Hermann Bondi and Thomas Gold, which is particularly interesting as it includes extensive discussion as well as the papers presented. (One participant is identified only as 'Mr. X'; the consensus is that he was Feynman. The fact that even Feynman didn't want his name to be associated with such discussions perhaps reflects the fact that many perceive them to be fringe or at least only marginally related to 'real science'.) Much modern discussion parallels that in that book; on the other hand, there has been progress, at least with respect to defining terms and making various points of view more clear, though there is still much disagreement about the nature of time, particularly time's arrow. This book is also the proceedings of a workshop (which took place in 2023 in Buenos Aires). The 16 authors of the 13 chapters (three have two authors) are primarily philosophers of science (though some work in physics as well). Many of the usual suspects are here, either as authors or cited in the references. (In most books on the philosophy of physics I have read, I came across various subsets of about thirty names; it is a relatively small field in terms of people actively working in it, though not in terms of scope.) The older book contains many authors known for their work in cosmology, astrophysics, astronomy, or General Relativity (GR), reflecting the fact that there was less specialization back then (and, of course, much less to know). These days, there are several full-time philosophers of physics, though many have a background in physics and most are very knowledgeable about physics, not just the philosophy thereof.

There is little actual astronomy in the book, even in the last, fourth part 'The Whole Universe'. On the other hand, most or all of the arrows of time are relevant for astrophysics, and the contributions provide a good overview of current thinking on the various arrows of time and the relationships among them. I was pleased to see two old papers (co-)authored by Tolman cited — not one of his many papers on entropy in cosmology (though his book on that topic[2] is) — but rather on thermal equilibrium in General Relativity[3,4]. I found useful the discussions on the distinction between time-reversal invariance, reversibility, and the arrow of time (Chapter 11) and on various ideas on how an arrow of time can arise even if the underlying physical laws are time-reversal invariant. An important role is played by the 'past hypothesis', a term coined by David Albert referring to the assumption that the Universe started in a low-entropy state[*] (and as such is a boundary condition rather than a law of Nature); most of the chapters cite his influential book on the topic[6]. There are, however, other ideas concerning the origin of various arrows of time, some of which I find intriguing and some of which seem to me to be rather desperate. Some of the contributions discuss the concept of free will and its relation to the arrows of time; there is certainly no consensus regarding free will[†], though I hope that most readers agree with me that the idea of free will being able to change the *past* as well as the future is going too far.

The writing and editing are good, especially considering that the editors and many of the authors are not native speakers of English, and there are fewer typos and so on than in most

*Penrose[5] discussed the idea of a 'special' state of the beginning of the Universe in a somewhat different context.

[†]I don't think that I could believe in it even if I wanted to.

books I've reviewed in these pages (though Kip Thorne is transformed into Kip Throne). There are just a handful of black-and-white figures; notes are footnotes and each chapter has its own reference list (as is often the case in the philosophical literature, titles of articles are included, which I find useful in general and prefer unless space is at a premium); a two-page small-print index ends the book. This is a good introduction to and overview of the topic, and the extensive references are a good starting point for those wanting to explore the philosophical literature not just on the arrow of time but on physics and cosmology in general. — Phillip Helbig.

References

(1) T. Gold (ed.), *The Nature of Time* (Cornell University Press) 1967.
(2) R. C. Tolman, *Relativity, Thermodynamics, and Cosmology* (Clarendon Press), 1934.
(3) R. C. Tolman, *Phys. Rev.*, **35**, 904, 1930.
(4) R. C. Tolman & P. Ehrenfest, *Phys. Rev.*, **36**, 1791, 1930.
(5) R. Penrose, in E. J. Fenyves (ed.), *Fourteenth Texas Symposium on Relativistic Astrophysics*, vol. 571, 249–264 (New York Academy of Sciences), 1989.
(6) D. Z. Albert, *Time and Chance* (Harvard University Press), 2000.

The Universe: A Guide to Everything, by Helge Kragh (Reaktion Books), 2026. Pp. 188, 22 × 15 cm. Price £17·95 (hardbound; ISBN 978 1 83639 179 1).

I've read most of Helge Kragh's books and reviewed[1] one[2] in these pages. Kragh is a well-known historian of science and has written many books on the history of cosmology. In the preface, he clearly lays out his plan for the book: "Rather than aiming to describe what the universe *is*, the focus is on how people have conceived the universe, from the ancient Greeks to the present. It is a partial and inevitably selective history of cosmology, the science of the cosmos. The modern universe is in many respects entirely different from that of the past, but it does have a connection to the thoughts about the universe that emerged more than two thousand years ago." [Emphasis and capitalization as in the original.] His book is a marvellous success, in terms of both content and presentation — the book is extremely well written, better than most of those by native speakers of English. Although of course it can't contain everything, Kragh's selection of topics, all of which are clearly explained*, are all good choices, and despite the necessary brevity he manages to mention some aspects which aren't usually mentioned. He does, though, spend the short first chapter briefly describing what the Universe *is*. Subsequent chapters cover the time up to Newton, stars and galaxies, and the expanding Universe (which includes not only standard relativistic cosmology which led to the current standard model, but also various alternative models, whether or not based on General Relativity). So far, so standard, but very well done. There is a thirty-page chapter on the Steady State model (only one page less than the longest chapter, the previous one on the expanding Universe). It was of course scientifically a dead end, but very important in the history of cosmology. (In contrast, Kragh notes that much of the work which now comprises standard references in the field received very little attention at the time: (some of) the works of Friedmann; Lemaître; Zwicky; and Gamow, Alpher, and Herman.) The penultimate chapter, 'New Horizons', covers such current topics as dark energy, the Hubble tension, and the standard or concordance model of cosmology. It is certain that those topics will remain not only a part of the history of cosmology but of cosmology itself. The final chapter, 'Beyond the Standard Model', discusses some for which the former is trivially true but perhaps not the latter: pre-big-bang cosmology, the far future and fate of the Universe†

*Kragh avoids common misconceptions involving the Hubble(–Lemaître) law (Kragh also suggests "Lemaître–Hubble"), cosmological horizons, cosmological expansion, the date of publication of the first paper on relativistic cosmology[3], the fact that Lemaître was *not* a Jesuit, *etc*.

†Although the laws of physics lend themselves just as easily to extrapolation to the future as to the past, the latter is much more popular than the former.