With such new observatories in operation, or about to be, I expected review articles that summarize the subject for those not immediately involved, but it was surprising that there was only one of real use, putting things into a historical context. There are, however, extensive original research articles on novel techniques like machine-learning, the association of coronal mass ejections with flares using statistical methods, and the capabilities of the Atacama millimeter-wave *ALMA* array applied to solar observations. Among the many short contributions from participants was one that caught my eye, connecting avalanches of MHD waves to nano-flare heating of the corona.

The high price tag of this slim volume will obviously be a deterrent to prospective buyers including even university libraries, and there is also the factor that many of the papers in these proceedings will now have appeared in solar physics journals. The quality of production is high, as would be expected from this publisher, but there are no coloured figures which would have been welcome for interpreting the many detailed images of the solar surface in some of the papers. — Ken Phillips.

On the Origin of Time: Stephen Hawking's Final Theory, by Thomas Hertog (Penguin), 2023. Pp. 326, 23·4 × 15·2 cm. Price £10·99 (paperback; ISBN 978 180499112 1).

Belgian cosmologist Thomas Hertog was one of Hawking's last collaborators; the book was written, at Hawking's request, to popularize their joint work, which goes against some of Hawking's earlier work. In some sense, it is similar to another book[1] recently reviewed[2] in these pages in that it is about Hawking, working with Hawking, and the results of that work, though this book concentrates more on the science. An undergraduate at the Flemish-speaking Katholieke Universiteit Leuven (Georges Lemaître was associated with the mostly French-speaking Université catholique de Louvain, which moved to Louvain-la-Neuve when the old site became Flemish-speaking in 1968), and after master's and doctoral degrees in Cambridge (the latter with Hawking), Hertog, after working in the USA, France, and Switzerland, returned to Leuven as a professor in 2011 (and is now head of the theoretical-physics group at the department of physics and astronomy). His collaboration with Hawking extended essentially until the latter's death in 2018.

The basic idea of Hawking and Hertog (H&H) is that, similar to biological evolution, the Universe — not just the outcomes of the laws of physics but the laws themselves — is best understood as the contingent result of (quantum) branchings during its history (perhaps influenced by future events), rather than something which one could, at least broadly, derive from first principles, thus going beyond the classical difficulty of computing deterministic outcomes *in practice* and even beyond quantum indeterminacy. If that sounds vague, then that is because it is, at least to me. Those interested in a short summary (but too long to reproduce here) by Hertog himself can read the section starting with the last third of p. 188.

Hertog does a good job of providing a necessary overview of the history of cosmology, especially since the advent of relativistic cosmology somewhat more than a century ago, with the narrative becoming narrower and deeper as the main topic of the book is approached. A longer-than-normal preface introduces Hawking and the H&H collaboration before the first chapter gives some necessary background on cosmology, from ancient times until today, and black holes. It is a good and interesting overview, and also discusses biological evolution and how one usually makes sense of it by following it backward in time. Then follows an overview of (the history of) relativistic cosmology, which is not too biassed in favour of Lemaître but perhaps still gives Friedmann somewhat too short a shrift. (Lemaître was a very important figure, but it might be reading too much into his works when it is claimed that he was the first to engage in quantum cosmology, not just metaphorically, but also that he foresaw Everett's many-worlds interpretation of quantum mechanics, 'decoherence', and even the H&H top-down approach to cosmology.) That sets the stage for an overview of quantum mechanics and the concept of duality, which will play an important role later on, and the no-boundary proposal of Hawking and Hartle according to which in some sense time turns into space in the early Universe and that space is curved so that asking what was before the Big Bang makes as little sense as asking what is north of the north pole. Modern inflationary cosmology and the idea of the Multiverse are introduced before noting that Hawking in his later years distanced himself from the latter. (Unfortunately, the Multiverse discussed is only that of eternal inflation; there are different types of Multiverses, some of which have been discussed in books[3–5] reviewed in these pages[6–8].) The meat of the book is in Chapters 6 and 7, the two longest chapters, which discuss quantum cosmology and the holographic principle, often in the context of the H&H top-down approach to cosmology. The final chapter, much shorter than the others, is much more philosophical in outlook, which to some extent feels tacked on, something I have encountered before[3,6]. Whatever one thinks of the ideas of Hannah Arendt and H&H, it seems a bit of a stretch to invoke the former in support of the latter.

The book is reasonably well written with about the usual number of typos and questionable style choices. Some things seem a bit confused, such as referring to the CMB as a "cosmological horizon" and the light deflection at the surface of the Sun as seen from Earth as less than "a few arc seconds" (it is about $1''\!\cdot\!75$). While Dicke was already doing science in the 1930s, I don't think that he was thinking about the Anthropic Principle (AP) then. Hertog's teleological description of Carter's formulation of the AP contrasts starkly with that of Lewis and Barnes[9,10], who claim that Carter has often been misinterpreted. A galaxy "nugget" instead of "core" was presumably garbled somewhere in translation, but is at least amusing. Of course General Relativity is concerned with gravitational waves, not gravity waves, and by now we should all know that Wheeler didn't coin the term 'black hole' (though he did popularize it). I don't know why Hubble's equation $v = Hr$ should be "infamous"; more important is that it is very general, not just in the case of a constant rate of expansion. It is certainly true that Einstein initially thought that non-static cosmological models were irrelevant mathematical curiosities; I don't know why the same claim is made about Friedmann. I'm not sure why Faraday is claimed to be Scottish; perhaps confusion with Maxwell. Our backward light cone converges primarily due to the expansion of the Universe, not due to the presence of matter within it. Zwicky wasn't the first to contemplate dark matter, not even the first to use the term (though arguably the first to claim that there is more of it than of ordinary matter). Regarding traditional observational cosmology, the description is wrong in a way strikingly similar to (but probably independent of) that in another book recently reviewed in these pages[11]. There are a few other things which are at best confusingly formulated and some interpretations with which I and many others disagree (though most of the latter are not important for the main narrative).

There are a few black-and-white figures scattered throughout the book as well as eight pages of slick-paper colour plates, most of which I haven't seen elsewhere. Particularly interesting are hand-made sketches and plots by

Lemaître and a Dutch-caption cartoon of de Sitter, in the shape of (the mirror image of) λ (symbol for the cosmological constant) blowing up the Universe like a balloon, noting that the cosmological constant is responsible for the expansion.* The bibliography is not a list of references (which appear in the end notes) but more a (good — I've read almost half) list of suggestions for further reading. Endnotes (24 pages) contain references, additional information, or both; there is a 15-page small-print index.

I didn't find the book convincing; whether that is the fault of Hertog or my own I don't know. The work of H&H not only goes against some earlier work by Hawking but also takes a definite stance on two rather hotly debated topics, namely the AP and the Multiverse.† A common criticism of those two topics is that they (can) explain (everything) in hindsight but lack in predictive power. That is also true of the H&H top-down approach to cosmology. (As my late history teacher used to say, just an observation, not a judgement.) Their comparison with Darwinian evolution is apt (and the title is a reference to Darwin's *On the Origin of Species*); details are not predictable from the theory itself, because randomness (mutations in the former case, quantum effects in the latter) plays a key role. Of course, the theory of evolution is good science, but differs from traditional physics theories in that the goal is not a series of increasingly fundamental explanations. (Reductionism also applies to evolution, of course, in the sense that mutations and so on are understood at a low level. The difference is that, at least in practice, that reductionism cannot be used to predict the higher levels.) The difference from other high-level topics in physics (chaos, complex systems, *etc.*) is that H&H claim that not just the outcomes of the laws of physics are emergent, but also the laws of physics themselves. That certainly qualifies, in the words of Carl Sagan, as an extraordinary claim which requires extraordinary evidence. The idea of H&H might work in some sense, but it remains to be shown that it works better than the AP and/or the Multiverse in cases where both approaches claim to be able to explain the same phenomena. Although even staunch supporters of the AP usually reject a strong version‡ which claims that observers (whether human or not, whether sentient or not) in some sense cause the Universe to exist, it is strange that H&H, while rejecting even the weak AP (which some would regard as a trivial tautology), have their own bizarre idea, namely that a delayed-choice double-slit experiment[16] can be explained by the choice affecting the past ('retrocausality', an interpretation not shared by Wheeler, who suggested that and other similar experiments); strange enough for explaining non-intuitive aspects of quantum mechanics, but quite a stretch for explaining the origin of the laws of physics.

There are two related problems which sometimes occur with (semi-)popular books about topics which are relatively new. One, which doesn't apply here, is that it is often not clear what is new and/or controversial and what is consensus. The other is more common: on the one hand, there are technical monographs, original papers, theses, and so on, and on the other (semi-)popular books and articles, with nothing in-between. The latter is difficult to avoid, perhaps

*That is actually not the case. There are expanding and contracting universes with and without a cosmological constant (which could be positive or negative). Historically, the first relativistic cosmological model was Einstein's closed-space static universe and the second de Sitter's flat model with exponential expansion, both of which have a positive cosmological constant (but of course Einstein's didn't expand). That was a time when even experts were confused.[12,13]

†My own view is that a significant fraction of the debate on those topics is due to confusion of terminology, people talking past one another, and so on; I discuss that in a recent article[14]. (Of course, there is genuine difference of opinion as well.)

‡Bostrom[15] counts thirty versions of the AP.

because of the lack of sufficient readership. Although a generic problem, it also applies here: those interested in more details have few if any options other than delving into the (sometimes very) technical literature. As it is a generic problem, the author is not to blame, but it is something which the reader should keep in mind.

Despite my reservations, the book succeeds in its goal of presenting the basic idea of top-down cosmology for a more general readership and can be a first step for those interested in the topic — it just shouldn't be the last step as well, but a big jump will be needed between the first and last steps. Other modern ideas such as the holographic principle and the black-hole information paradox are explained well, so it can be a jumping-off point for those interested in modern ideas in quantum cosmology and related fields. — Phillip Helbig.

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The Einsteinian Revolution. The Historical Roots of His Breakthroughs, by Hanoch Gutfreund & Jürgen Renn (Princeton University Press), 2024. Pp. 249, 23 × 15 cm. Price £28/$32 (hardbound; ISBN 978 0 691 16876 0).

The Einstein industry marches on, almost 70 years since it was begun by the sorting of the mass of papers he left in Princeton at the time of his death in 1955. Those papers and the rest of Einstein's estate were left to the Hebrew University of Jerusalem, which still owns copyrights and such, though the on-going 'publications of everything' (the Einstein Papers Project) is now headquartered at Caltech, under the general editorship of Diana Kormos Buchwald. This enables the present authors to cite everything he wrote in the form CPAE* Vol. Number, Document Number, Page Number. We thereby gain access to the actual texts of letters he wrote to his first wife, to his friends Michele Besso and Marcel Grossman, and to very many of the other physicists and mathematicians who were his contemporaries. An unfortunate result is that the published Einstein papers also end up being cited in the form CPAE 2, Doc. 3 and CPAE 6, Doc. 21, rather than by year, volume, and page number

*CPAE is the Collected Papers of Albert Einstein