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REVIEWS

Conjuring the Void: The Art of Black Holes, by Lynn Gamwell (MIT Press), 2025. Pp. 208, 22·9 × 30·5 cm. Price $44·95 (about £33) (hardbound; ISBN 978 0 262 04996 2).

Gamwell is a non-fiction author and art curator, her books concentrating on the relationship between science, its history, and art. When encountering 'black holes' and 'art' in the same phrase, I usually think of Peter Galison (director of the Black Hole Initiative, philosopher, professor of the history of science and physics at Harvard, author, and film-maker), and indeed he is the first person thanked in the extensive acknowledgements. After a foreword by Neil deGrasse Tyson and an Introduction, there are three chapters of vastly different lengths: 'Black Hole Basics' (24 pages), 'Historical and Philosophical Background to Imaging Black Holes' (18), and 'Artistic and Scientific Images of Invisible Objects' (126), followed by a one-page 'Conclusion'. Each chapter has several sections (three, four, and ten, respectively) which more or less alternate between science and art (or, in either case, its history). Thus, we have the sequence (at the end of the third chapter) 'Supermassive Black Holes', 'Black Holes as a Metaphor for Nothing, Silence, and Blackness', 'Gravitational Waves Caused by Merging Black Holes', 'Immersive Art About Black Holes', and 'Direct Observation of Black Holes by the Event Horizon Telescope'.

The science sections are at the level of a *good* popular-science book, probably better than all summaries of similar length I've read; they are correct but understandable and concentrate on the important features. Good is that Wheeler is *not* credited with coining the term 'black hole' (though he did much to popularize it), and a case is made (probably correctly) that the term is due to Dicke. We get a good overview of the history of the black-hole idea and of the most important concepts. Many of the figures related to science are from technical papers, and there is a spectrum from those, through scientific 'artist impressions', through cartoons and sketches, through quasi-realistic art, to abstract art. While many readers are probably familiar with Jean-Pierre Luminet's classic black-hole image, we are shown other examples from around the same time. I was pleased to find out that Luminet is also an artist; one of his drawings is reminiscent of the work of M. C. Escher (and the front cover of the album 'Inside the Triangle' by 1970s band Thee Image — the back cover features a band photo which will probably be too much for those who didn't live through those times). Whether Luminet's image or those from (simulations of) the *Event Horizon Telescope*, we get not just the pretty pictures but also the explanation of how they were made and what they actually show.

I know more about science than about visual arts. As in the sections about the former, in those about the latter we get summary texts and illustrations, though understandably the image-to-text ratio is higher in the latter case. Most of the art is modern and most art I like is not modern, but all the same I found both the text and image portions of the art sections interesting. There are also tie-ins between the modern science of black holes and related ideas in other times and cultures, but fortunately what is emphasized are interesting parallels, not *Tao of Physics*[1]-style woo.

This is a beautiful book. The dust jacket contains a hole, revealing a circle of black velvet (or something similar) in the centre of the front cover. I refrained from my usual penciled-in notes in the margins, putting them on a blank page at the end instead. However, very few were necessary, as there are almost no typos nor other things I often complain about in reviews. Somewhat unusual are headers and page numbers at the bottom of the page (and only on pages which are not solely devoted to figures and captions — there are many pages which are). All of the images are in colour except the few which are originally black and white, and the large format and slick paper make for an enjoyable reading experience; considering the high production standard, the price is more than reasonable. Five pages of endnotes are mostly references, but one is a very long list of 30 popular-science books in English about black holes published since 2020. (I've reviewed four of those in these pages [2–9], and several others I've reviewed from the same time also touch on black holes; there is no shortage of literature.) The page of 'Photo and Diagram Credits' contains only those which are not in the corresponding captions; since there are illustrations on nearly every page and many pages devoted solely to illustrations and their captions, there are many of the latter. An index corresponding to a bit more than three full pages ends the book.

There is also no other book like it. Whether for the combination of science and art or for a good overview of either, this is a good introduction to black holes and their role in our thinking. — Phillip Helbig.

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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.