being quite rapidly resolved in favour of the former by the first thermal-plasma measurements by Soviet and US spacecraft. However, the subsequent issue of the distance to the shock that terminates the supersonic outflow, and from thence to the heliopause boundary with the interstellar medium beyond, was only resolved by *Voyager* particle and field data during the past ~20 years, following a debate that lasted for almost 50 years. The third issue covered in space-plasma physics concerns the properties of the Earth's magnetosphere, whether magnetically 'open' as proposed by Jim Dungey in 1961 or closed as argued by Alex Dessler, on which indirect evidence in the 1960s and 1970s and direct evidence principally in the 1980s and 1990s ruled in favour of the former.

In addition to briefer discussions of some less-controversial topics such as the discovery of the Earth's radiation belts by James Van Allen, the book also covers four significant debates in planetary physics. The first two concern the origin of the Earth–Moon system, the subject of many past hypotheses but now considered to have resulted from the impact between a Mars-sized body and the early proto-Earth, and, much later in Earth's history, the cause of the Cretaceous–Paleogene mass extinction event and its association with the Chicxulub asteroid-impact crater originated by Alvarez *père et fils*. A related topic concerns the depth of the dust layer on the lunar surface produced by meteorite bombardment, which Tommy Gold in 1955 suggested might be sufficiently deep in some locations that astronauts would disappear up to their armpits or beyond, a speculation happily disproved by space missions preparatory to the Apollo landings.

More infamously, in 1986 Lou Frank proposed on the basis of spacecraft ultraviolet imaging initially intended for auroral studies, that the Earth's upper atmosphere is being continuously bombarded (several per minute) by small cometary bodies that would have profound significance for Earth's water budget. This assertion triggered 17 years of lively debate involving no less than 32 papers, comments, and rebuttals published by Frank and colleagues, together with experimental studies by others, that ended with the general perception that these signals were, after all, due only to instrumental effects within the auroral-camera system, a conclusion that appears never to have been acknowledged by the proponents. As the contents of this fascinating book make clear, though the 'scientific method' of testing, verification, and refutation does eventually sift the scientific wheat from the chaff, the length and nature of that process may depend significantly on the human personalities involved. — Stanley W. H. Cowley.

The Era of Multi-Messenger Solar Physics, edited by Gianna Cauzzi & Alexandra Tritschler (Cambridge University Press), 2023. Pp. 160, 25 × 18 cm. Price £120/$155 (hardbound; ISBN 978 1 009 35288 8).

This volume is the Proceedings of IAU Symposium 372, co-ordinated by IAU Division E with other working groups, which was held in Korea in 2022 August at the tail-end of the Covid pandemic. The nearly 80 contributors were mostly from Asia but with some from the US. The main motivation for the meeting was the recent solar space missions, *Solar Orbiter* and the *Parker Probe*, and the *Daniel K. Inouye Solar Telescope*, largest ground-based solar observatory in the world, still in its commissioning phase at the time of the conference. The 'multi-messenger' of the conference title refers to the way these and other solar observatories are gaining knowledge of, for example, the connection of the magnetic fields in the distant solar atmosphere with the magnetic field at the solar surface.

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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

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