worse, and he was less alert mentally. Those changes continued, with visits to hospital with heart problems, and he died peacefully of heart failure in George Washington University Hospital on Boxing Day 2020. His 1972 camera still sits on the Moon's surface and serves as a suitable memorial for this remarkable man.

I must now comment on the writing style. DeVorkin gives a lot more detail than I have included here and makes a digression every time he introduces a new person with a significant effect on Carruthers's career. That makes it quite difficult to discern a clear path through Carruthers's development and progress. That is true of the whole book, which makes it hard to see the wood for the trees. I think this would have been a better book if he had restructured it so that the digressions were separated off into separate coherent chapters and didn't interrupt the flow of Carruthers's story. However, it is easy to follow each individual paragraph, and I found myself reading easily and, in the end, reading every word. So — would I recommend this book? It is certainly a comprehensive account of the life and work of the man DeVorkin calls a "Quiet Genius", but there is so much detail that it is hard to remember it all, which perhaps makes it more of a reference book. It is useful therefore that there is a 20-page index. There are also 61 pages of notes — mostly just references to sources but including occasional comments — as well as a 21-page bibliography of the books the author has consulted. There is a useful list at the beginning of the meaning of many acronyms, such as NRL, and at the end there is a brief glossary of scientific terms. He also lists all the oral-history interviews by himself and others (six with Carruthers himself) and his archival resources. Unusually, he also includes brief profiles of four of Carruthers's students and mentees, including quotations from them of their opinion of Carruthers (all favourable!).

If you want all that detail, then this book can be recommended. But if you just want to find out quickly who the man was and what he achieved you may be better to consult his entry on Wikipedia (https://en.wikipedia.org/wiki/George_Robert_Carruthers). — Robert Connon Smith.

Reading the Mind of God: Johannes Kepler and the Reform of Astronomy, edited by A. E. L. Davis, J. V. Field & T. J. Mahoney (Springer and the RAS), 2024. Pp. 405, 24 × 16 cm. Price £79·99 (hardbound; ISBN 978 94 024 2248 1).

The very first word in the first chapter of this book is "Surprising." In that case the surprise is Kepler's very deep religious conviction. It is true that in most history-of-science primers Kepler's faith is rarely mentioned except as causing him annoying logistical difficulties by occasionally having to move home from one city to a more tolerant one. The editors' comment that in a book organized according to what was most important to Kepler, his theology takes first place. Thus, the initial chapter, subtitled a 'Theological Biography', on Kepler's religion and his commitment to Lutheranism, written by the theologian Charlotte Methuen, reveals his uncompromising approach on matters of theology, to the extent that may have made life very difficult for a less talented, and thus less socially tolerated individual. The second chapter, by J. V. Field, considers his religion in relation to his belief that the heliocentric cosmogony shows the nature of the creator. Kepler's deep belief in God as the creator and geometer of the Universe was the central driving force to his scientific efforts and that is persuasively argued in those first two chapters. Field takes us through Kepler's published works, including *Mysterium Cosmographicum* and *Harmonice Mundi*, the two books which link the geometry of the orbits of the then-known six planets. Kepler placed the five Platonic solids to nestle between their orbits, which they fit astonishingly well; in fact the inscribed and circumscribed spheres (at the faces and at the vertices) of each polyhedron create spherical shells the thicknesses of which accurately bound the eccentricities of the planetary orbits — surely unequivocal proof of God's geometry. It is not surprising then, that religion underpins the unlikely looking title of this collection of essays. However, the surprises do not stop with religion: Kepler had described the concepts, and indeed designed

the optics for astronomical telescopes before Galileo; he also developed the beginnings of using infinitesimals to calculate the area of difficult shapes — perhaps sowing the seeds of calculus. In his study of volumes constructed from regular polygons he discovered two new Archimedean solids; his description of how the Universe would look from the surface of the Moon resulted in the first science-fiction story; and he came up with the concept of a force emanating from the Sun as being responsible for the planetary orbits. Despite all that he was not a modern physicist; he still believed in astrology, but in his semi-rational physical version, believing that just as the Moon causes the tides it would not be surprising if, through similar action at a distance, the position of the planets could affect the environment of a person's birth. He was a traditionalist to the extent that he did not make use of algebra, believing it untrustworthy as it allowed for "non-constructable" phenomena, thus his calculations of planetary orbits were carried out using Euclidian geometry, based on straight-edge-and-compass diagrams and page after page of tedious arithmetic. Although he had advanced from the ancient medieval alchemists, he was certainly a scientist of his time, but a key, perhaps *the* key, scientist leading to the 17th-Century scientific revolution.

This book has had a seemingly long gestation period of 15 years. Although published in 2024, it grew out of special session on the life and work of Kepler at the General Assembly of IAU held in Rio de Janeiro in 2009. That session was organized to mark the four-hundredth anniversary of the publication of Kepler's *Astronomia Nova*, which introduced his first two laws of planetary motion. The session organizers had gathered the leading Kepler experts in all branches of his work, and their meeting was regarded as a huge success. (T. J. Mahoney's minutes of the meeting are available on-line.*) Because the conference and its proceedings were deemed to be rather too technical for general appreciation, a working group was formed to develop a programme to promote Kepler and ensure that his huge contribution to science was more widely known. One proposal was to make the conference contents available in book form, but in a version aimed at a sophisticated readership but one not necessarily as familiar with all the details of Kepler's life as the conference attendees. What was needed was a good, serious, detailed book about most things Kepler (there are too many for all), and this volume is the result.

The 13 chapters are written by experts as diverse as theologians, astronomers, mathematicians, space scientists, teachers, and linguists. In addition to religion and its influence on Kepler's cosmology — mentioned in the first two chapters — subsequent essays cover: T. J. Mahoney's account of the astonishing accuracy of Tycho Brahe's astronomical instruments, which provided the data that led Kepler to his first two planetary laws; A. E. L. Davis's description of the mathematics — by geometry — that led to those laws; Andrew Gregory's analysis of the single word in Greek in the full title of the otherwise Latin *Astronomia Nova*, and the difficulties in decoding the word which can be interpreted to mean both explanation and cause and therefore presents problems to later Kepler scholars. Kepler's unconventional approach and reform of astrology are covered by Shiela Rabin in a chapter in which Kepler is said to dismiss the signs of the zodiac as the products of a peasant's imagination, and rejects astrology's predictive power, stating that the stars instruct they do not compel. But he also describes astrology as financially necessary for him, and that it benefits his study of astronomy. On optics Kepler is on modern ground and W. H. Donahue describes, with contemporaneous drawings, Kepler's leading role in that science and his use of ray diagrams, a technique seemingly borrowed from the artist Dürer. The design of lenses for telescopes led to a correspondence with Galileo and their relationship is examined in Chapter 8 by J. V. Field, simply titled 'Kepler and Galileo'. That relationship was initiated almost by accident, as an acquaintance of Kepler's travelling to Italy had been instructed to pass on a copy of *Mysterium Cosmographicum* to professors of mathematics, which in

*https://www.researchgate.net/publication/231990068_Marking_the_400th_Anniversary_of_Kepler's_Astronomia_nova

Padua just happened to be Galileo. Galileo's friendly letter of thanks and Kepler's enthusiastic response are reproduced here in English translation. The next chapter, also by J. V. Field, considers the *Rudolphine Tables*, which enabled accurate calculation of the future positions of the Sun, Moon, and planets from an initial observed position. That work started by Tycho based on his observations was completed more than 20 years after Tycho's death by Kepler using his own model of planetary motion, including elliptical orbits, and makes use of his third law. Jay Pasachoff in the next chapter on observing planetary transits notes that the 3rd law is the key to uncovering the planetary content of the Universe by means of the *Kepler*, *TESS*, and *CHEOPS* spacecraft. He discusses some of the difficulties of observing transits as exemplified by the 1761 transit of Venus which had the aim of establishing the scale of the Solar System. He makes the point that centuries after his death, Kepler's work has led directly to a flourishing branch of astronomy today in the study of extrasolar planets. Chapter 11 by Eberhard Knobloch outlines some of Kepler's contributions to mathematics which include his philosophical belief that in geometry existence is equivalent to constructability and thus non-constructable items cannot be known to the human mind or by God. Thus, Kepler rejected algebra, despite which he made huge mathematical contributions, some of obviously geometric concern, like polygons and polyhedra, but also conic sections, logarithms (the tables of logarithms in the *Rudolphine Tables* were from Kepler's own calculations), the precursor of infinitesimal mathematics and calculus, and strangely the ideal shape for wine barrels. The penultimate chapter by Jarosław Włodarcyk tells us of Kepler's science-fiction story *Somnium* ('Dream') which he had been writing for most of his adult life, although it was not published until after his death. Kepler's *Dream* describes a journey to the surface of the Moon and the conditions that might be experienced there, with an accurate description of the cosmos as seen from the lunar surface. There had been numerous earlier authors of such journeys but because they had used wild imagination and were from a geocentric, stationary-Earth perspective they are regarded as fantasy. Kepler's view of the lunar skyscape is based on his thorough, accurate calculation from a heliocentric viewpoint which gives it a factual basis and makes it science fiction.

This range of authors, and subjects assembled from such individual skill, knowledge, and enthusiasms, might need firm editorial control to achieve a coherent whole with a consistent level of intellectual demand of the reader. However, the editors have, quite rightly in my opinion, decided not to impose a unified version of Kepler, but have allowed the distinguished experts to express their own views by their own methods. That necessarily results in variation of styles. A one-time colleague of mine describes as 'viscous' passages and book chapters that require repeated rereading or simply cause an 'er what!' response. The sticky viscosity of some chapters in this book is understandable from the editors' light-touch approach. For the reader, enthused by the introductory passages, some of the chapters' technicalities can be overwhelming. That becomes particularly troublesome when an author makes repeated references to Kepler's or other published works in order to describe an exchange of view. Those other works may well be on the bookshelf of the expert, but however copiously footnoted and referenced in the essay, those writings are not within reach, or even a simple mouse click away from the general reader. The true enthusiast will persevere and follow the link to the on-line sources* in Latin and German, and will doubtless be rewarded *via* the arcane paths of mathematics, theology, Latin, Greek, and post-medieval German to a richer understanding. However, if you are accepting of being occasionally baffled, and being just carried along with the expert enthusiasm, then this book works as an enjoyable read for the non-specialist who will be awed by Kepler as an amazing scientist, one who led the way to our rational understanding of the Universe. He lit the path to modern data-driven physics and in so many instances built the ladder for others, such as Galileo and Newton, to climb to greatness.

*https://kepler.badw.de/en/kepler-digital.html

The last chapter, written by W. H. Donahue, an author and translator of Kepler into English, describes the careful nuance required in revealing the intention and meaning in translating writing, diagrams, and even print layout of work from a different time and culture. He hopes for more of Kepler's work to made accessible in the form of readable, well-annotated selections, in translation, for the general reader. In that last chapter, on the last page and in the last paragraph, we find this: "Kepler is too good to be constrained within the province of experts". Amen to that. This book is a serious work and not a light-weight popularizing book for public understanding, but it does a very good job in making the astonishing range and achievement of Kepler's work more widely accessible — so much of which is presented in English translation of Kepler's own words. As befits its expert scholarly origins this book is thoroughly referenced at the end of each, well-footnoted, chapter. Additionally, there is a very useful chronology covering the relevant period, from the birth of Martin Luther in 1483 to the end of the thirty years war in 1648, plus a glossary of terms including those that are now obsolete or have changed meaning over time, and finally there is a 28-page index.

This book is an absolute joy; there is not one chapter that does not delight or surprise. It is detailed enough for the serious scholar who might want a jumping-off point to research a particular aspect of Kepler's work, but enough enthusiastic description for the amateur who simply wants to get into the mind of Kepler, to try to understand just how he arrived at his understanding of the cosmos. It should be made available in all libraries wherever science is studied. — Barry Kent.

The Universe: A Biography, by Paul Murdin (Thames & Hudson), 2022. Pp. 288, 24 × 15·5 cm. Price £31·99 (hardbound; ISBN 978 0 500 02464 5).

Not to be confused with *Secrets of the Universe*, *Mapping the Universe*, *Universe*, *Discovering the Universe*, or *Catalogue of the Universe* (all (sub)titles of books (co-)authored by Murdin, who has about a score altogether), this book offers a chronological overview of the history of the Universe (with the time since the Big Bang on the upper right of the rectos), starting off with discussions of Olbers's paradox and the expansion of the Universe, the "questions that revealed the universe was born". Murdin is well known for his work with Louise Webster identifying Cygnus X-1 as the first convincing black-hole candidate; that story is told in more detail in a book[1] recently reviewed[2] in these pages than in this book. The following chapters cover the early Universe, galaxy formation, the dark ages, the Milky Way, the Sun, end phases of stellar evolution, the origin of the Solar System and Earth's Moon, the structure and history of Earth, the future of the Universe, and a discussion of the cause of the expansion. (Note that the last two chapters, though numbered as expected, are referred to as 'sequel' and 'prequel', perhaps reflecting their somewhat more speculative status.) What differentiates this book somewhat from similar books is more emphasis on the people involved (though of course much less than in books on the history of astronomy) and integrating related topics into the appropriate chapters, covering such subjects as big-bang nucleosynthesis, the cosmic microwave background, dark matter, primordial fluctuations, expansion, surveys, gravitational lensing, Messier objects, active galactic nuclei, radio astronomy, gravitational waves, the Lyman-α forest, H I intensity mapping, galaxy mergers, *Gaia*, Sgr A*, meteorites, the faint-young-Sun problem, the Carrington Event, X-ray binaries, chaos in the Solar System, Milanković cycles, life, plate tectonics, planetary magnetic fields, mass extinctions, and *eLisa* — thus fleshing out a more or less standard qualitative history with a bit more astrophysics, in many cases in somewhat more detail than in similar books.

As with many authors, Murdin's discussion of the relationship between the geometry and destiny of the Universe is that of a universe with no cosmological constant, though Murdin, of course, notes elsewhere that that is not our Universe. The ultimate conclusion, that our Universe is (almost) flat and will expand forever, is technically correct, but obscures the important point that the latter (assuming a Friedmann model the parameters of which we