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REVIEWS

Planetary Geology: An Introduction, 3rd Edition, by Dominic Fortes & Claudio Vita-Finzi (Liverpool University Press), 2025. Pp. 318, 26 × 20 cm. Price £31·99 (paperback; ISBN 978 1 78046 104 5).

Planetary Geology, by Fortes & Vita-Finzi, gives a thorough and up-to-date overview of this topical and rapidly advancing subject. It covers more or less all aspects of planetary geology, from the basic origin of the Solar System, orbital physics, and geophysical techniques, to crust-building processes, atmospheres and cryospheres and the possibility of volcanism, plate tectonics, and life on non-terrestrial planets.

The book is information-rich and must have been an enormous undertaking. The complementary specialties of the authors have enabled excellent integration of knowledge concerning Earth, about which we clearly have information gathered close-up that provides unique detail, and the other planets, most of which we can study only remotely. Integration of information on such disparate scales is challenging. However, the authors have effectively achieved what they set out to do.

It is a courageous undertaking to produce a book on this subject in the face of the almost monthly announcements of significant new findings. However, the content has been effectively designed to maintain relevance in the face of rapid advancements. A read of this book equips the reader with an excellent overview and basic understanding of most aspects of the subject on which to build as new advances are made.

The book is beautifully produced and a pleasure to read. It is scholarly, and assumes a readership with a good general scientific grounding. At the same time, it is well readable and attractively and abundantly illustrated in beautiful colour. It also provides a good level of detailed data in the form of tables and charts. Given that, it will have wide utility for students, teachers, scholars, and interested lay persons. It provides an excellent supporting text for courses and can function as a basic reference volume on the bookshelves (for those of us who still have such things) of all Earth scientists. I recommend it highly as a supporting text to courses on planetary geology. — Gillian R. Foulger.

From the Laboratory to the Moon: The Quiet Genius of George R. Carruthers, by David H. DeVorkin (MIT Press), 2025. Pp. 434, 23 × 15 cm. Price $75 (about £55) (paperback; ISBN 978 0 262 55139 7).

I had never heard of George Carruthers, and I suspect most astronomers not involved in instrument development may share my ignorance. And yet he played a vital role in the Apollo programme and in earlier attempts to discover what happens above the Earth's atmosphere. This book explains how and why.

Born in 1939, Carruthers's family were part of the professional middle class, unlike the vast majority of other African Americans at the time (his Uncle Ben taught at Howard University in DC). He was brought up on a farm, where his father had worked hard to make the farm buildings useable and liveable, setting an example of hard work that his son followed throughout his career. He helped his father, who had a background in civil and general engineering, to fix things around the farm. The farm was run for just themselves, and his father worked during the week at an Air Corps base in Dayton, Ohio, and told young Carruthers many tales of what he saw there. His school grades were excellent, and his private reading mostly involved how to build flying machines in air and space. He also made designs for spacecraft and wrote "quite corny" stories about space flight. With his father's help and encouragement, he made himself a small refractor and loved looking at the Moon, planets, and stars, so he became very excited when people like von Braun started talking seriously about space rockets being possible and useable for astronomy.

His father died young, when Carruthers was about six, and the family moved to Chicago to live with his grandmother and great aunt. At his new school, several science teachers guided him through experimental work, at which he excelled. He also built himself a better telescope, a reflector for which he ground the mirror, with the help of the Adler Planetarium, which ran programmes for young people. After school, he went to the Champaign/Urbana campus of the University of Illinois to pursue a degree in engineering, where he found himself for the first time in a mostly White environment. However, he encountered little direct racism — mostly the White students simply ignored him. That didn't bother him, because he had always been a loner and just continued his goal of learning enough to get involved in space flight. He was particularly keen on working in the laboratories, and it was practical work with a special interest in cameras and in the engineering of rocketry that became his life's work. He even set up his own laboratory in his mother's basement while he was still a student. He was always trying risky things and had plenty of mishaps as a result. Much later, he had a sign on his office wall saying, "If it ain't broke, let's see if we can break it."

After graduation, he obtained a summer job at the Aerojet Corporation in California, his first introduction "to what engineers actually do" and discovered that he didn't like being one cog in much larger wheel — he wanted to see the whole picture. After that, he pursued graduate study, studying aeronautical and astronautical engineering combined with a minor in physics and astronomy, which introduced him to some of the astronomy faculty. He chose a thesis topic that was very precise but which he knew would give him insight into how rockets would interact with the Earth's atmosphere. He built all his own laboratory equipment, which involved becoming a competent glassblower and learning about photoelectronic detectors. During that time, he gave a very-well-received talk about his work, at the Naval Research Laboratory (NRL), which much impressed Herbert Friedman and led to Carruthers joining Friedman's group at NRL in Washington, DC, where he moved in 1964. He began working on sounding rockets (Aerobees, built at the Aerojet Corporation) and designing and building instruments to fly on them, with special concentration on the UV radiation expected to be produced by nebulae around hot stars. He first designed and built a low-resolution spectrophotometric camera of a new design that was a hybrid of a camera introduced in the 1930s by Lallemand and modern (1960s) electronography and would be sensitive in the far-UV. It would present the results as two-dimensional images. However, his desire (and ability) to do everything himself annoyed the NRL technical staff and created some difficulties, which he ignored. They got used to it.

By that time, his skill and dedication had won him support and admiration from the science community and he began to be in demand for a variety of projects. Despite his first love being his camera, which he kept tweaking and improving (he patented one version), he did accept other work, such as developing a night-vision programme of interest to the navy. Friedman arranged for him to become a full-time staff member at NRL. One of his first achievements there (in 1971) was the first detection of molecular hydrogen in space in the UV, from a sounding rocket, which added to his growing reputation amongst astronomers. In his first cameras, the images were recorded on film, which needed to be returned to the ground for processing, but later technology enabled him to use electronic recording (CCDs by the 1990s) which could be returned to Earth digitally. He started to publish regular articles reviewing the technology.

He had also started, as early as the 1960s, to write NASA proposals for instruments to be used in the Apollo programme. He made many such proposals, but they kept being turned down by committees. The main aim of Apollo was to put men on the Moon and use them to explore its properties, and it was difficult to persuade anyone that astronomy was a priority. Carruthers's case was that his camera could record the whole geocorona and its auroral patterns for the first time, as well as providing a stable platform for many other astronomical observations. He began to get support from Thornton Page (described as a "consummate networker"), who had made his own more elaborate proposal for a 20-inch telescope on the Moon. After much politics in high places, a combined proposal was accepted for Carruthers's small camera to be taken on *Apollo 16*. Unfortunately, the camera design was too large to fit into the Lunar Module (LM), even folded up — so a new design was called for, still retaining both imaging and spectroscopic modes. The launch date was fixed, so there was great pressure on all parties to meet tight deadlines. Finally, the flight took off and landed safely, but six hours later than planned, requiring both Carruthers and Page rapidly to recalculate the altitudes and azimuths of the objects they wanted to observe from the alt-az mount. It was then up to John Young to set up the telescope in the shadow of the LM. He did that successfully and many images were recorded on the film roll, which was brought safely back to Earth. There followed many months of anxious waiting before the results were known. They were able to present a few unique and impressive images and spectra at the AAS meeting in 1972 August, but it was years before all the data had been fully processed.

The *Apollo 16* images led to a flurry of public interest, particularly among the local Black Caribbean community, and he began to be invited to visit schools and talk about his work. He turned out to be an excellent speaker and good with children, so those invitations kept coming. Some of those talks were arranged by Francis Redhead, a prominent member of the Caribbean community, and he had a daughter, Sandra, so those public events led indirectly to his marriage to Sandra, who helped her father to coordinate the speaking events.

The *Apollo 16* success spurred him on to new projects, the first of which was *Skylab*, where his Apollo package was used on *Skylab 4* in 1973 November to observe the close approach of Comet Kohoutek to the Sun. Although many useful results were obtained by Carruthers and others, to the public the comet was a disappointment because it did not brighten as expected. He applied for every new project (the Shuttle, *IUE*, *LST/Hubble*, *etc*.) on which he could use his camera to record images and spectra. He even applied to become an astronaut but was not accepted. He stuck with his original electronographic camera design but was constantly improving it and updating the recording device as new detectors became available, such as CCDs in the late 1980s onwards. His enthusiastic mentor, Friedman, retired in 1981 and was replaced by Gursky, who was equally supportive. However, funding became scarce as NASA's support dwindled after the *Challenger* disaster in 1986, which stopped all manned space flights for three years, and Carruthers's far-UV group was especially badly damaged, losing staff to other areas. Gradually, Carruthers's role as leader became more that of consultant and mentor of students.

Carruthers never threw anything away, and gradually took over new laboratory space, the cost of which had to be borne by NRL. His success rate for new projects also started to decrease, because new members of staff were tending to avoid using his camera, regarding it as now out of date, even though its spectral range stretched as far as Lyman-alpha. He had been promoted to a very senior rank, but had too few grants to cover his space costs, which was causing management problems, and he was eventually moved out into a 40-foot trailer attached to the main building. That move coincided with (and perhaps prompted) his increased activity in outreach, where he was one of the originators of an apprenticeship scheme and supervised many summer students and year-long co-op students. By the 2000s, his outreach activities were becoming increasingly visible. That was not a new interest — he had given a motivational talk in 1960, when he was still in college, to a conference of mainly minority schoolchildren. That was not his only outside interest. He also felt strongly about encouraging more minorities and women into science, and he joined the NTA* and became very active within it, even spending several years as editor of its journal and making the NTA itself better organized. He also got involved in S.M.A.R.T. Inc.† which quickly became a way of making direct contact with students, their parents, and teachers to advise them on what school subjects were needed to succeed in those areas. NRL was happy to support those outreach activities because they were a good advertisement for the lab. By that time, he was well known nationally and had received many awards for his work, including the AAS's Helen B. Warner Prize for his discovery of molecular hydrogen. The most prestigious award was The President's National Medal of Technology and Innovation, presented to him by President Obama in the White House in 2013. The citation specifically mentions his "invention of the Far-UV Electrographic Camera".

In 2002, Carruthers took retirement, aged 63, under a scheme devised by Gursky by which he was rehired for another ten years with full access to his lab, where he appeared almost every day and which he used as a base for his increasing work with students. On retirement, he also became an adjunct professor at Howard University in DC, the students of which he had already been in contact with for many years. Carruthers had been promoted early in his career in recognition of his work, and continued to be paid well, so he and Sandra were comfortably off and he was able and willing to help close family members with loans and gifts, as his brother Gerald gratefully acknowledged. The final chapter of the book gives more details of his family life, including his wife's death in 2009 and his subsequent second marriage in 2011 to a colleague and helper whom he had met in 2004, Debra Thomas. But even by the time he received the Presidential Medal in 2013, his physical health was getting

*The National Technical Association, founded in the 1920s by 'Black technical, scientific and professional engineers'. It encouraged African Americans to enter jobs in science, engineering and technology. By the late 1980s, its membership had risen to some 500,000.

†S.M.A.R.T. stands for Science, Mathematics, Aerospace, Research and Technology, founded in 1985 as a group 'to advise on science and technology issues of importance to the Black community'.

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 have correctly determined) is certain whether or not the Universe is exactly flat or has a slight positive or negative curvature (whereas in the case without a cosmological constant the flat case is a boundary not only with regard to geometry but also with regard to destiny); also, our Universe will not "slow its expansion but never completely stop" — that is the Einstein–de Sitter Universe with no cosmological constant and the critical density — but rather is now accelerating and will asymptotically approach the exponential acceleration of the empty de Sitter model. (See ref. 3 for more details on that common mistake.) A few other common misconceptions are repeated, *e.g.*, the first indications of dark matter came in 1933 through the work of Zwicky (see ref. 4 for references to earlier work). That the Big Bang resulted in 96 per cent hydrogen and 4 per cent helium is incorrect; closer to the truth are 92 per cent and 8 per cent, respectively (in addition, it is not stated that the values are by number of atoms, rather than by mass, in which case the (correct) values are 75 per cent and 25 per cent, respectively). His discussion of the expansion of the Universe being the outcome of an "explosion in which various fragments are thrown out at different speeds" is more reminiscent of Milne's Kinematic Relativity than standard cosmology. While the former also results in a velocity–distance law of the form $v = HD$ (where v is the recession velocity, H the Hubble constant, and D the proper distance), in standard cosmology the recession velocity is (in general, and in our Universe) not constant. In such a universe (and in the 'equivalent' Friedmann model with neither matter nor a cosmological constant) the reciprocal of the Hubble constant is always the age of the Universe; in our Universe, it is so near the present time; that appears to be a coincidence which holds only near the present time[5] (rather like the coincidence in the angular sizes of the Sun and Moon). Sometimes statements depend on a context which, however, is not always clear; I'm sure that the clustering of galaxies was noted before a 2001 paper by Peacock and Cole. Like his use of Λ-CDM rather than ΛCDM, Henry for Heber Curtis, and Ralph for Rudolph Minkowski (nephew of Hermann who, like Walter Baade, moved from Hamburg to Mt. Wilson), such issues demonstrate an unfamiliarity with cosmology. While no-one can be an expert on everything, either the publisher or the author should get enough experts to read the manuscript so that all areas are covered (including the very confusing last paragraph of the main text). However, those goofs are made up for by Murdin not only avoiding the common misconception that John Wheeler coined the term 'black hole' (though, as Murdin correctly notes, he did popularize it), but (very probably correctly) also attributing it to "Robert Dicke about 1961"[6,7*]. A non-cosmological mistake is mentioning the supernova of 1054 in connection with the Bayeux tapestry; the latter probably shows what was later known as Halley's comet, not a supernova, which was visible in 1066. While I suppose it is conceivable that "*Homo sapiens* took to living in caves about that time, perhaps motivated to shelter because of the risk of severe sunburn", I don't see any causal connection with "that time", which refers to the last major reversal of the Earth's magnetic field about 800 000 years ago.

The book is a bit hard to pigeonhole. Like a book[10] reviewed here a year ago[11] it is a long narrative, though that book is told as a history of astronomy and this one as a history of the Universe; both, however, contain details not always found in similar books. It is mostly up to date (though my former employer was never known as the Nuffield Radio Astronomy Observatory and hasn't been known as the Nuffield Radio Astronomy Laboratories for a long time) and there are many references to other sections of the book. Maryland (mentioned in connection with Gamow, Alpher, and Herman) is not a suburb of Washington, DC, but maybe that is just a typo and an 'in' is missing. Another typo is the depth of the CfA survey at 400 million light years; 400 Mpc is correct (though the caption on the corresponding illustration correctly has 1·3 billion light years).

Note that in addition to the 288 numbered pages (the front matter is also roman-numbered)

*Note that the author of ref. 7 is the same as that of ref. 8, a book, reviewed in these pages[9], which I very highly recommend.

there are 16 pages of colour plates, half of which are near the beginning and half near the end of the book. I probably would have chosen similar illustrations, but not devoted a quarter of the plates' pages to simulated images of the future merger of the Milky Way and Andromeda galaxies. The only other figures are line drawings at the beginning of each chapter, illustrating the corresponding main topic. There are neither footnotes nor endnotes. The main text is followed by a seven-page glossary then, in small print, picture credits and an eight-page index. The book comes with a dust jacket, but beneath that the binding is covered by a CMB map from *Planck* and its mirror image, joined at the spine.

On the whole, this book is a good broad overview of the history of the Universe, but one sufficiently different that most readers will probably run across something which they haven't read before. Despite the qualms mentioned above it could be a good first book on the topic. (I mentioned more qualms than usual as I'm sure that the author will appreciate the curmudgeonly attention to detail and the exacting standards of this *Magazine*[12].) — PHILLIP HELBIG.

References

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(10) M. Capaccioli, *The Enchantment of Urania: 25 Centuries of Exploration of the Sky* (World Scientific), 2024.
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THESIS ABSTRACT

PLANETESIMAL BELTS IN MISALIGNED WIDE STELLAR BINARIES

By Steven Young

Some main-sequence and post-main-sequence stars show signatures of close-in hot dust which cannot have formed there or been produced *in situ* as the collisional time-scales at these locations are much smaller than the ages of the systems. Hence, there must exist some dynamical mechanism to deliver rocky bodies to small distances on time-scales of 10–10^4 Myrs. This thesis examines the feasibility and detectability of one of these potential mechanisms: the eccentric Kozai–Lidov effect (Eccentric Kozai Mechanism, EKM) whereby a stellar companion on a misaligned wide orbit perturbs planetesimals to high eccentricities. First, in order to explain the mysterious light-curve of KIC 8462852, one component of a wide binary-star system in the *Kepler* field with deep, irregular, and aperiodic dips in its