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