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Reference

(1) *Nature*, **47**, 582, 1893.

REVIEWS

Resolving the Rise and Fall of Star Formation in Galaxies, edited by Tony Wong & Woong-Tae Kim (Cambridge University Press), 2023. Pp. 333, 25 × 18 cm. Price £98/$130 (hardbound; ISBN 978 1 009 35295 6).

This volume is the proceedings of IAU Symposium 373, held in Busan in the Republic of Korea in 2022 August as part of the XXXI General Assembly. According to the preface there were 21 invited talks, 36 contributed talks, 78 e-posters, and 78 e-talks at the symposium. This has translated into 71 printed papers — many of them very interesting — split into five (somewhat overlapping) sections: 'Scales of Star Formation: From Molecular Cores to Galaxies' (19 contributions), 'Sustaining Star Formation: Gas Conditions & Environment' (also 19), 'The Decline of Star Formation: Feedback, Fuel Shortage or Inefficiency' (9), 'The Rise and Fall of Star Formation Across Cosmic Time' (14), and 'Regulation of Star Formation and the Evolution of Galaxies' (10). The organizers' intention was to draw together work on the full range of scales, and they certainly achieved that, though it would be interesting to know exactly how much those participants primarily involved with large-scale surveys or cosmological simulations were able to take away from papers on, say, ultra-compact H II regions or hot molecular cores (and *vice versa* of course). A conference overview or summary would have been useful. A plus point of the volume is the wide geographical spread of institutions and individuals among the contributors, but a negative is that many of the results had already been published (in more detail) in journals prior to the meeting and more will have appeared by now. The latter point raises the wider question of the on-going value of such volumes. With journals moving towards on-line only, why does a conference have to have a printed book (apart from them being pleasant souvenirs for attendees)? Does anyone seek them out and search them for new work anymore, or simply check astro-ph? — Steve Phillipps.

Inside the Stars, by Hugo Van Horn (IoP Publishing), 2023. Pp. 252, 26 × 18·5 cm. Price £30/$50 (hardbound; ISBN 978 0 7503 5792 0).

Our understanding of the Universe today, and in particular of the structure and evolution of stars, is vastly different from what it was when I started as a research student in 1963. The classic textbooks on stars, which I acquired early in my research career, were those by Eddington (1926), Chandrasekhar (1939), and Schwarzschild (1958), with the latter describing how to make numerical models of stellar structure by the laborious 'fitting method'. Van Horn's book starts with a masterly introduction to those early days, starting with the first attempts in the 19th Century to understand what a star is and how it works. As an American (as one can deduce from the spellings), he makes more of the pioneering work of J. Homer Lane than I have seen elsewhere. During Lane's time at the US Patent Office (shades of Einstein!) he began to wonder whether the Sun might be gaseous (a liquid or even solid interior was a more common view at the time) and thought about the balance between gas pressure and gravity that we take for granted today. He later (1870) produced what were probably the first polytropic models of a star, which may have inspired the later work of Ritter and Emden in Europe.

By the time of Schwarzschild's book, the modern view of a star had emerged, and our understanding of stars progressed rapidly. Van Horn's stated aim is to explain how we know about the interiors of stars and how we can deduce the internal properties from surface observations. At first sight, the structure of the book is similar to that of any other modern text on stellar structure, 19 separate sections, the longest of which are the early ones, but it is different in its approach and style. In Section 1, the first short chapter gives a broad overview of what a star is before discussing observations of the Sun as a star in the next chapter. Van Horn then turns to the physics, with short chapters on radiation, composition, and energy sources before describing the properties of the material inside stars — equation of state, opacity, and nuclear-reaction rates. In all the chapters, he introduces the principal players in the field, often with short anecdotes and a photograph, many of which were new to me. His writing style is informal but precise, making for easy reading, and he often quotes from an interview with Martin Schwarzschild by the oral historian William Aspray in 1986.

In Part 2, a closer look at the interior of the Sun covers three important topics — how we came to understand the present Sun, the detection of neutrinos, and the use of helioseismology. The first of these describes the improvement in computations once digital computers became available* and once Henyey had introduced his method using an approximate model and then using difference equations to find a converged model, Schwarzschild happily gave up his fitting method in favour of this more efficient procedure.

I remember the agonizing in the physics community over the 'solar neutrino problem', where all the predictions came out 2 or 3 times the observed flux. It was not finally resolved until 2004 when the *SNO* device in Canada measured the total neutrino flux and it was realized that the Sun emitted the predicted number of electron neutrinos but that neutrino oscillations between the Sun and the detector turned about two thirds of them into mu and tau neutrinos, which only *SNO* was set up to measure. My then-Sussex colleague David Wark (now in Oxford) was part of the *SNO* consortium, so we heard all the details at that time.

*I remember Roger Tayler telling me once of the months he spent in the 1950s calculating stellar evolution on a manual calculator for his PhD.

We are all familiar now with the concept of asteroseismology, but the 'five-minute oscillations' of the Sun were a surprise when they were first discovered by Robert Leighton in 1960. It took a decade before they began to be understood as the p-modes (sound waves) predicted by Tom Cowling in 1941. Like neutrinos, these sound waves gave us a way of discovering conditions inside the Sun, including the temperature, density, and rotation distributions and the existence of a transition layer (the tachocline) between the differential rotation in the convective envelope and nearly uniform rotation in the radiative core. UK contributions to helioseismology (*e.g.*, the BiSON group in Birmingham and Douglas Gough in Cambridge on the theory of interpreting the observations) are well described.

In Part 3, Van Horn turns to stars, using the Sun as a reference point and starting with the properties of main-sequence stars. That leads naturally on to discussions of star formation and of brown dwarfs, stars that are too cool to burn hydrogen at their centres. In Part 4 the action moves to stellar evolution and death. These seven chapters cover what happens to stars of low mass when they run out of hydrogen to burn (the 'He-flash'), how intermediate-mass stars become white dwarfs, the properties of white dwarfs, the evolution of high-mass stars, supernovae, neutron stars, and finally stellar-mass black holes, which are introduced with an account of the detection of gravitational waves from a pair of merging black holes. This part is the meat of the book, and proceeds in the same style, following the development of ideas from the 1950s to the present day and mentioning in passing such items as Hoyle's 1950s prediction of a resonant level in the ^{12}C nucleus to explain how the triple-alpha reaction to form carbon from helium works fast enough, and Faulkner's 1966 explanation of the horizontal branch in globular clusters.

Van Horn gives a lot of detail of how a star evolves, both for low-mass stars like the Sun and for intermediate-mass stars, including careful discussion in the latter case of the various stages of dredge-up as the convective envelope extends down into zones of mixed composition produced by previous convection in material processed by nuclear burning. He mentions thermal pulses on the asymptotic giant branch, mass loss, planetary nebulae, and neutrino emission. He then turns to stellar remnants, such as white dwarfs, introduced by the discovery of 40 Eri B and Sirius B; he discusses how Chandrasekhar was able to explain in the 1930s how those hot dense objects could exist, although he doesn't mention Chandrasekhar's struggles to get his model accepted in the face of Eddington's scornful disbelief, expressed trenchantly at a meeting of the RAS. However, he does give a full discussion of the physics of white dwarfs, including their observed atmospheric properties and the cooling mechanism explained by Leon Mestel in the 1950s.

The evolution of more-massive stars ($> 8\ M_\odot$) leads not only to supernovae but their remnants, both expanding shells and a remnant imploded core. Van Horn describes succinctly the successive nuclear fuels that are burned, leading to an 'onion skin' structure of the layers of burned material of successively higher atomic mass until an iron core has formed. He describes the explosion mechanism, in which neutrinos appear to play a vital role in ejecting the shell that becomes a gaseous nebula, and why the iron core collapses. The resultant super-dense remnant is either a neutron star or, if too massive for that, a black hole. He also discusses SN 1987A and the detection of its neutrinos, as well as reviewing other types of supernova and how Type I supernovae explode, laying out the uncertainties. Three further chapters cover the origin of the chemical elements (Big Bang and in stars) and the physics of neutron stars (with a nod

to the discovery of pulsars by Jocelyn Bell). The binary pulsar is mentioned as a test of General Relativity, and X-ray bursters also get a mention. The third chapter discusses stellar-mass black holes and gravitational radiation. Van Horn was present at the historic event where the positive *LIGO* results were announced and gives a graphic account of the excitement. The final three chapters cover stars with special characteristics — pulsating stars, cataclysmic variables, and the first stars.

There are six appendices expanding on some topics, such as electron degeneracy and *LIGO,* plus an extensive bibliography as well as relevant references at the end of each chapter. I had a few gripes. Firstly, I dislike page numbering by chapter (1-1, 1-2 *etc.*), so that it is laborious to find out how many pages the book contains (I have not checked the number claimed by the *Magazine*'s Editor [who crudely adds the numbers given in the list of chapters — Ed.]). More seriously, there is no general index, so one has to rely on the List of Contents to see whether any particular topic is covered. If you wanted to find out whether a particular astronomer gets a mention, you would have to guess which chapter he or she might be in. A list of illustrations would help with that, but there isn't one. I hope that if there is a second edition the publisher might deal with those points.

In summary, then, a very comprehensive and attractively written account of stellar structure and evolution, let down slightly by editorial deficiencies. I would still recommend it warmly for those wanting to know the details of what goes on inside stars. It covers advanced material at a level that would be useful for final-year physics undergraduates and beginning graduate students in astronomy, but it is written in a style suitable for less-advanced students. Members of many astronomical societies would appreciate it. But beware: it weighs 872 g! — Robert Connon Smith.

Physics of Binary Star Evolution. From Stars to X-ray Binaries and Gravitational Wave Sources, by Thomas M. Tauris & Edward P. J. van den Heuvel (Princeton University Press), 2023. Pp. 852, 23·5 × 15·5 cm. Price £80/$95 (paperback; ISBN 978 0 691 17908 7).

The evolution of binary-star systems sounds like one of those dull but worthy fields worked arduously by the older and more-bearded members of a typical university astrophysics department. This is wrong to the point of mendacity. The evolution of binary systems depends on juicy physics and leads to some of the weirdest and most wonderful objects within astrophysics, including cataclysmic variables, X-ray binaries, multiple types of supernova, millisecond pulsars, gamma-ray bursts, and the progenitors of gravitational-wave events.

Due to the variety and complex interrelations between many of these objects, the research in this area can be a bit compartmentalized and difficult to develop an intuitive feel for. This is perfect territory for a hefty textbook where the many threads can be pulled together into a coherent overview of the subject. Such a textbook requires extensive knowledge and understanding from the authors, the space to cover all relevant points, clear writing that engages the reader, and careful organization to aid their understanding. Tauris & van den Heuvel have produced exactly this textbook; it is a masterpiece.

The book begins with a brief but informative review of history of the many types of binary star (astrometric, spectroscopic, eclipsing, cataclysmic variables, X-ray binaries, supernovae, and others). Celestial mechanics gets the same treatment, followed by the Roche model, mass transfer, tides, accretion discs, common envelopes, white-dwarf binaries (both wide and close), and more. The bulk of the book is dedicated to the ménage of X-ray binaries, as might

be predicted by those familiar with the research interests of the authors. Topics covered include LMXBs, IMXBs, HMXBs, and ULXs, and the discussion begins with the observational viewpoint before moving on to the theoretical framework. A clear description of the evolution of single stars follows, and then is extended to cover the evolution of stars in binary systems. The final chapters concern interacting binaries in globular clusters, supernovae, binary and millisecond pulsars, gravitational-wave events, and binary-population synthesis. More detailed treatments of some of these concepts are available elsewhere, but Tauris & van den Heuvel cover a huge amount in one place. It goes well beyond what a typical 'binary stars' module would cover at the undergraduate level, and will be useful for anyone undertaking research in this area from PhD students onwards.

The writing style throughout is clear and easy to read, which is impressive given the material covered. There are many diagrams, illustrating both physical concepts and observational data, and a good number of pretty pictures. Colour is present in those pictures and in the majority of the diagrams. Careful attention is paid to tracing the evolutionary pathways of binary systems, which can otherwise be hard to tease from other sources. A fair number of exercises are given at the end of many of the chapters, with (extremely brief) answers in an appendix. The book is also produced to a high standard, and I did not find any grammatical or typographical errors. Tauris & van den Heuvel's book has immediately become the standard text in this science area and I recommend it unreservedly. — John Southworth.

Astronomy of Ancient Egypt: A Cultural Perspective, by Juan Antonio Belmonte & José Lull (Springer), 2023. Pp. 588, 21·5 × 15 cm. Price £129·99 (hardbound; ISBN 978 3 031 11828 9).

In 1969, the great historian of science, Otto Neugebauer, wrote: "Astronomy played a uniformly insignificant role in all periods of Egyptian history." And the present authors tell us: "However, there is not a single explicit or obvious reference to any lunar or solar eclipse in the entire history of Pharonic Egypt" (with the possible exception of a 610 BC* event). That remark occurs on page 516, leaving one to wonder what the previous 515 pages have been about.

The last, seventh, chapter deals with astronomy and chronology. It is followed by a generous glossary, a long list of works consulted, and a moderate index. But the chronological issues are real. When, for instance, did Khufu (Cheops) of the Fourth Dynasty build his pyramid (the biggest one)? Table 7.1 presents three chronologies from earlier authors in which Cheops' dates are 2554–2531 BC, 2589–2566 BC, and 2509–2482 BC, not even overlapping, and Belmonte and Lull tell us that all three are wrong.

By the time of the much-romanticized 18th Dynasty, the various numbers are at least overlapping, and the authors defend a chronology that puts Tutankamun's nine-year reign in 1322–1314 BC†. But numbers from all the authorities do not entirely converge until we reach the reign of 25th dynasty Pharaoh Taharqa, 690–664 BC, when Egyptian and chronologies from other civilizations can be synchronized.

*The Managing Editor and I have previously disagreed about the proper abbreviation for years long ago. I have a strong preference for CE (Common Era) and BCE (Before Common Era). The present authors, however, use AD and BC and are entitled to their insensitive choice.

†Zahi Hawass, in *Tutankhamen: Treasures of the Golden Pharaoh* (IMG Melchior, New York), 2018, chooses 1336–1327 BC in a volume that came with the higher-priced tickets to a presentation in San Diego in spring 2013, part of his national fund-raising tour. He also declared during the book-signing event that "Badawy was a genius", a point to which I shall return.

There are, of course, carbon-14 dates for materials from various periods. Most of these have error bars that extend across all reasonable choices. Years of spikes in C-14 contents of tree rings* happen not to come close in time to interesting events in Egyptian history. And a solar eclipse recorded only by nearby civilizations† is too late at 1209 BC to constrain anyone before Merneptah and Ramesses II (the Great), who were already pinned down to within plus/minus a couple of years anyway.

We turn with relief to things that can be observed and measured today. First, the book itself is gorgeous, printed on paper glossy enough for the colour photographs to look real and for names in hieroglyphs printed within lines of ordinary text to be readable (if you are at least a little bit used to reading such things). Yes, modern technology has made it possible for every major publisher, not just Oxford and Chicago University Presses to have full sets of hieroglyphic type fonts. These are based on carved versions dating from the Middle Kingdom, and I was greatly pleased to spot the stack of three wiggly lines (read mw or mu, which is close to the Coptic word for water), the one sign correctly interpreted by Athanasias Kircher (1598–1680), which form part of the name of a dean‡ called Stars of the Water.

As for what is illustrated and named in the book, two of the important topics are alignments of temples, pyramids, and other buildings and images of the sky, or at least its constellations. Alignments of faces, entrances, corridors, shafts, and such favour the cardinal compass points and the directions of sunrise and sunset on the solstices often enough for the authors to conclude that these must have been deliberate and determined from observations, and not just a tendency to make things parallel to the Nile (their Figures 6.6 and 6.7, for instance). The preface to the book discusses at some length how those alignments might have been achieved using various possible astronomical observations, plumb lines, and artificial horizons. One alignment not discussed is "the controversial issue of the air-shafts in the Great Pyramid as hypothetical stellar channels" because the senior author has already written on the topic in a 2012 book on "*Piramides, templos, y estrellas*" (that is, in Spanish, his native language). A harsh attack on the hypothesis¶ is, however, cited without comment. It is not often that an author receives the dubious honour of being attacked for something published 55 years before (60 by the time this appears), and I made no attempt to respond at the time. But here, for the record, is what I believe to be the first published suggestion on the controversial issue: "They are usually thought to be ventilation-channels, but would be better considered as open ways for the king's soul to reach the circumpolar stars to the North and the Orion constellation to the South."§

As for the images, some are cosmogonic, for instance, a very brightly coloured version of the sky goddess Nut being held up by the air god She, who is in turn supported by the Earth god Geb (Figure 1.4), though we have to skip to page 232 to

* See Miyake event on Wikipedia and keep your fingers crossed we don't have another one soon.

† C. J. Humphreys & W. G. Waddington, *A&G*, **58**, 5.39, 2017

‡ A group of a few stars used to tell time at night.

¶ R. Krauss in *Studien zur altaegyptichen Kultur*, **48**, 151, 2019. '*Die Kanaele in der Cheops-Pyramide: Luftschaechte, Modellkoridore oder Leitwege zu den Sternen?*' in German, his native language.

§ Page 138 of *A History of Egyptian Architecture*: Vol. I. *From the earliest times to the end of the old kingdom*, by Alexander Badawy, Architect, Cairo, 1954, the author being at that time an associate professor at Cairo University, a member of the Egyptian Exploration Society, and so forth (1913–1987).

find the epagomenal decan of the Senenmut list called sh-t-w-i, the Two Turtles. And as this is a family publication, I am probably not allowed to tell you what Nut and Geb are doing in Figure 1.13. There are also many illustrations of constellations and related patterns of stars in the sky, many clearly distorted from what was actually seen. The question most often asked is whether, and if so how, the Egyptian constellations are related to the ones we learned from the Babylonians, the Greeks, and the International Astronomical Union. The standard answer has been that Orion is recognizable as a striding man and the hippopotamus includes Sirius. The authors, however, have evolved a "working hypothesis" that identifies many more of the patterns shown in the Dendara astronomical ceiling (which you must now travel to Paris to see), including a Zodiac with Gemini, Taurus, Leo, Pisces, Cancer, and so forth, with the planets scattered among them. Their Sirius lives in the head of a recumbent cow, though the hippo is there (page 305) and seems to be carrying a folded umbrella.

Let us end with one item that lets us feel at home. The standard symbol for a celestial body (pronounced, roughly, seba) is a "five pointed star formed by an internal dot and five rays. The universal five-pointed star symbol presumably originated in Egypt in pre-Dynastic times" (page 540). — Virginia Trimble.

The ALMA Telescope. The Story of a Science Mega-Project, by Paul A. Vanden Bout, Robert L. Dickman & Adele L. Plunkett (Cambridge University Press), 2023. Pp. 264, 24·5 × 17 cm. Price £39·99/$49·99 (paperback; ISBN 978 1 009 27968 0).

ALMA took over 30 years to gestate, during which a great many committees, working groups, boards, and similar organizational bodies came and went. Each involved the dedicated services of numerous scientists, administrators, technicians, and financiers, and won the support and gratitude of innumerable (if understandably a little impatient) would-be users worldwide. This book is in many senses a corporate journal of the multitude of events, tasks, decisions, and recollections of how *ALMA* finally emerged in all its unique and transformational glory. An inevitable consequence is that the story moves painstakingly slowly, at times a little too much so, but the authors were present officially at, or not far removed from, the action during much of the period in question, thereby endowing the book with the status of a reference manual as well as a finely-interrelated collection of facts and figures.

This story of *ALMA* commences right at the start when a project of such magnitude could not be more than a pipe-dream, but that first distant whisper was sufficiently fertile to tickle the imagination of the more powerful activists among communities of millimetre and infrared astronomers, building on projects like the USA's *Millimeter Array* (*MMA*) already advanced in planning. And although it is freely admitted that this account of *ALMA* has been told from the perspective of the USA, in the end *ALMA* became a world project, not just an enhanced one owned and operated by that country alone. Indeed, as the concept slowly morphed into *ALMA* it became clear that one country alone simply could not manufacture, staff, or (most importantly) fund the entire project in all its complicated and detailed magnificence. A consequence of that somewhat myopic view is that no mention is made of the fact that it was British and Canadian radio astronomers who made breakthroughs in interstellar molecular physics, or that the all-important success with such a fundamental procedure as 'very long baseline interferometry' (VLBI) was initially a Canadian achievement.

The story is charmingly illustrated with cameos involving key players, some revealing things said *sotto voce*, even best left unsaid, that serve to brighten up the reams of details. Despite the eventually unchecked progress of the telescope from early idea to full completion, not everything was plain sailing, and the cliff-hanging description of the USA's very hesitant agreement at a late stage to accept the grossly enlarged budget for the telescope adds a welcome seasoning of excitement that brings its journalistic style alive. One aspect that could have been thought through differently was the wisdom to include specific costs in all their rather gory details. While indeed part of the journal, writing the exact figures with so many noughts might appear a bit vulgar to the general public (and to astronomers routinely strapped for cash), when descriptive words like 'several thousand million' would be more appropriate for a 'story'.

The book is generally well written, though the USA's habit of ignoring conventional grammar (including vital hyphens and commas) caused me some exasperation. Very few typos or other mistakes are apparent — until the final chapter, where the margins of several pages proved inadequate for me to pencil in all the corrections that I itched to make. The book includes a brief Appendix that explains the rudiments of radio astronomy and its attendant equipment, and (fortunately) it sports a 4-page 'Glossary' of the many acronyms that pepper the book freely, and (as with the costs) several could with advantage have been replaced by simple descriptive words. It will make interesting reading for the inquisitive public and for astronomers not directly involved, while primarily offering a fine set of reminiscences for the many who were so involved. It is a remarkable product of industrious archival research, and deserves a place on both science and departmental bookshelves. — Elizabeth Griffin.

Annual Review of Astronomy and Astrophysics, Volume 61, 2023, edited by E. van Dishoeck & Robert C. Kennicutt (Annual Reviews), 2023. Pp. 616, 24 × 19·5 cm. Price from $444 (print and on-line for institutions; about £365), $122 (print and on-line for individuals; about £100) (hardbound; ISBN 978 0 8243 0961 9).

The 2023 *Annual Review* begins with a remarkable story of a lady, raised in a Christian family in China, who rose to international prominence in the field of geodesy *via* long-baseline radio astronomy. Shuhua Ye overcame the turbulent history of her homeland in the latter half of the 20th Century to join the top ranks of the IAU and make a significant contribution to studies of Earth rotation and the establishment of accurate time services.

Starting at the beginning of time we find a tantalizing account by Klessen & Glover of the first stars to be formed — the so-called massive Population III stars (with masses up to $10^5 M_\odot$) — which will be hard to observe but particularly interesting because of their metal-free composition. Also at the 'Cosmic Dawn' we have a discussion of the earliest quasars by Fan *et al.*

A review I found particularly interesting was by Jewitt & Seligman on 'Interstellar Interlopers', a couple of which have been found wandering through the Solar System; it is thought that they may be planetesimals ejected from protoplanetary discs. The chemistry of volatile elements in such discs is examined by Öberg *et al.*

On the grand scale, we find a study of galaxy-cluster dynamics using hydrodynamical simulations by Crain & van de Voort, while swirling around those assemblies will be the circumgalactic medium whose processes are covered by Faucher-Giguère & Peng Oh.

On the smaller (but still vast) scale is the interstellar medium within the Milky Way, which is addressed by McClure-Griffiths *et al.* who consider the role of atomic hydrogen, and on an even smaller scale in accretion in the environment of binary stars by Lai & Muñoz. While we know quite a bit about the generation of magnetic fields in stars, it came as something of a surprise to me to find that galaxies themselves have dynamos, outlined in the work of Brandenburg & Ntormousi.

On the instrumental front we have a report on imaging spectroscopy of radio emission from the Sun by Gary, and on advances in interferometry, especially ESO's *GRAVITY* instrument on the *VLTI*, by Eisenhauer *et al.* And finally an elaboration of the benefits of Gaussian processes in the analysis of time-series data by Aigrain & Foreman-Mackey. — David Stickland.

America's First Eclipse Chasers. Stories of Science, Planet Vulcan, Quicksand, and the Railroad Boom, by Thomas Hockey (Springer, in association with Praxis Publishing), 2023. Pp. 444, 24 × 16·5 cm. Price £27·99/$37·99 (paperback; ISBN 978 3 031 24123 9).

Professor Thomas Hockey is well known for his authoritative and well-written historical studies. One recalls, for instance, his excellent *Biographical Encyclopaedia of Astronomers* and his *Jupiter before Voyager*. The present book looks back at the total solar eclipse of 1869, with the imminent prospect of yet another such event being visible from America in 2024.

In 1869, it had been four years since the Civil War of 1861–65, an apocalyptic national event. In those times, as the country was returning to normality, the recent growth of the railroad, racing ever westward to link the east and west coasts of America, was to play a key role in the eclipse expeditions of 1869 and later. It was now possible for astronomers and their bulky luggage to travel *en masse* to witness a total solar eclipse upon American soil.

Observations of total solar eclipses don't always go smoothly. When choosing a spot from which to watch one from India in 1995 I was threatened by an armed guard when innocently straying onto the pitch claimed by another group. Here, as Hockey follows the many and varied groups that travelled to position themselves beneath the long track of the Moon's shadow in 1869, the battle for legroom was hardly an issue: it was more a question of what facilities an isolated frontier town could offer to a scientific party. It is likely that Simon Newcomb carried a pistol in his luggage when he travelled to Des Moines, Iowa. Although there aren't any Tombstone-style shootouts in this book, some expeditions literally shot themselves in the foot through basic error and incompetence, while others succeeded admirably.

There is the story of the retired Naval Commander who bumped into his telescope, shaking his precious long-exposure photographs; how E. C. Pickering avoided the crowds and stayed safely in his hotel room to observe, simply propping up his telescope and spectroscope on a chair in an amateurish manner; and so on and so forth. Others were still wasting their time to look for the non-existent planet Vulcan. It is interesting that Asaph Hall, the leader of one party, once had to host President Lincoln when he had called unexpectedly one evening at the US Naval Observatory to do some practical observing, while Edward Curtis, who carried out spectroscopic work with Professor Harkness (also part of the USNO expedition), was a former pathologist turned photographer, and one who had performed the autopsy upon the assassinated Lincoln. The 1869 spectroscopic work was perhaps the most interesting from a

scientific point of view, leading as it did to the discovery of the coronal green line.

The pioneering spirit pervades this enjoyable romp through the American mid-west. I highly recommend it. It is richly illustrated, and I have honestly only ever seen one or two of the illustrations previously. (Figure 5.1, by the way, is printed upside down. There are few obvious typographical errors.) There is a very good collection of portraits of individuals, observing locations, charts, and drawings and photos of the eclipse. Hockey's book offers sound background details, and nicely sets the 1869 events and discoveries in context. It can either be read from cover to cover or just dipped into at random, as the chapters are self-contained. It is an engaging work, always informative and comprehensive, and — in quite a few places — highly amusing. And what about that quicksand mentioned in the title? Well, I leave that to Hockey's readers to discover, but I might just add that the unfortunate Naval Commander was involved. — Richard McKim.

Nobel Prizes in Astronomy, by Pushpa Khare (Springer), 2023. Pp. 173, 23·5 × 15·5 cm. Price £22·99 (paperback; ISBN 978 3 031 29638 3).

Strictly speaking, there are no Nobel Prizes in Astronomy, but we all know of cases where a Nobel Prize in Physics has been awarded for work very strongly related to astronomy. Research significant enough to merit a Nobel Prize is often not easily explicable to high-school students and we owe this book to Dr. Khare's daughter, who suggested that she wrote an account suitable for students. Recently retired from Utkal University, near Pune, and with plenty of experience in giving popular talks and writing for science magazines, she took up the challenge.

She covers 13 Prizes, starting in 1967 with the award to Hans Bethe for his work on what we now call nuclear astrophysics: the nuclear reactions that happen inside stars and provide the energy source for stars. She recognizes seven categories: 'Stellar Structure', 'Stellar Evolution', 'Radio and X-ray Astronomy', 'Extra-solar Planets', 'Black Holes', 'Gravitational Waves', and 'Cosmology', and devotes one chapter to each category. For each Prize (sometimes several in each chapter) she starts with the citation, followed by some biographical information about the recipient (complete with a photograph in most cases; she did not in time receive permissions for two). She then gives appropriate background information, which for Bethe runs to 12 pages (an overview of the whole of stellar structure), followed by an account of the specific work for which the Prize was awarded.

As well as Bethe, the first chapter includes the 2002 award jointly to Ray Davis Jr. and Masatoshi Koshiba, mainly for their independent 'detection of cosmic neutrinos', using, respectively, the Homestake mine and *Kamiokande* (originally set up to look for proton decay; the full name is *Kamioka nuclear decay experiment*). Davis recorded solar neutrinos, but for a long time there was a puzzle: he detected only about a third of the expected number. It wasn't until the much later *SNO* experiment that it was realized that neutrino oscillations had reduced the number of electron neutrinos during the journey from the Sun to the detector. Koshiba's first detection was of neutrinos from SN 1987A, but later his group confirmed Davis's results for the solar neutrinos. *Super-Kamiokande* was able to detect muon neutrinos and confirmed the *SNO* result.

The 'Stellar Evolution' chapter records the 1983 Prize, shared between Chandrasekhar (essentially for the 'Chandrasekhar limiting mass' of a white dwarf, although the citation is much wider) and Fowler for his seminal work

on nucleosynthesis in stars (the famous B^2FH paper is duly mentioned). The next chapter covers two separate Prizes, the 1974 Prize to Ryle and Hewish for radio astronomy and the 2002 Prize to Giacconi for X-ray astronomy. The 1974 citations pick out the invention of aperture synthesis for Ryle*, and "his decisive role in the discovery of pulsars" for Hewish. Jocelyn Bell is of course mentioned, but with no comment on the subsequent controversy. The 2002 citation for Giacconi mentions particularly "the discovery of cosmic X-ray sources", the first of these being Scorpius X-1. He shared the Prize with Davis and Koshiba (see previous paragraph). The differences between optical, radio, and X-ray telescopes are carefully explained.

The idea that there might be planets around other stars has existed for many years, probably for millennia in the more general sense of whether there might be life elsewhere in the Universe, but it was only in 1995 that the first discovery was announced by Michel Mayor and Didier Queloz. They received the 2019 Prize "for discovery of an exoplanet orbiting a solar-type star." Together they had developed a technique that enabled them to measure radial velocities to an accuracy of 10 to 15 m s^{-1}, sufficient to detect very small variations in a star's velocity caused by the orbital motion of a planet around the star, and in 1994 they detected a periodic variation in the motion of the star 51 Pegasi.

The 2020 Prize was awarded to three people: the mathematician Roger Penrose and two observers, Reinhard Genzel and Andrea Mia Ghez, for work on black holes. In 1965, Penrose had shown rigorously that Einstein's general theory predicted the formation of black holes, while Genzel and Ghez in the late 1990s discovered that our Galaxy has a massive black hole at its centre, as had been speculated nearly 30 years earlier.

General Relativity (GR), of course, also features in gravitational waves. Russell Hulse and Joseph Taylor received the 1993 Prize for their work in the 1970s on the binary pulsar, which they observed initially to find the mass of the pulsar. However, they also observed a slow decrease in the orbital period, which they attributed to the emission of gravitational waves. Careful measurements showed a very close agreement between the observed decrease and that predicted by GR, providing indirect evidence for the existence of gravitational waves. Much later, after many attempts to detect gravitational waves directly, starting with Weber's seminal experiments in the early 1960s, three other physicists, Rainer Weiss, Barry Barish, and Kip Thorne developed the idea of laser interferometry (first suggested by two Russian physicists, Gertsenshtein and Pustovoit in 1962) into the *Laser Interferometric Gravitational wave Observatory* (*LIGO*). *LIGO* successfully detected a signal on 2015 September 15 and the award of a Nobel Prize for this work came remarkably quickly, in 2017.

Cosmology has received no fewer than four Nobel Prizes, from the 1978 Prize to Arno Penzias and Robert Wilson for their accidental detection of the cosmic microwave background radiation (CMBR) in 1965 to three this century. The related work by George Smoot and John Mather showing that the CMBR has a pure black-body spectrum and that it has anisotropies at the 10^{-5} level received a Prize in 2006. The discovery by Saul Perlmutter and separately by Brian Schmidt and Adam Riess of the acceleration of the expansion of the Universe was published in 1997 and they received the Prize jointly in 2011. Finally, Jim Peebles was rewarded for a lifetime's theoretical work in physical cosmology by a share in the 2019 Prize (shared with Mayor and Queloz — see above).

*The author gives a percipient quotation from a letter, published posthumously, where Ryle says, "Our cleverness has grown prodigiously — but not our wisdom."

This is an interesting and informative book, written for high-school students but with plenty of stories of interest to other general readers and to professional astronomers. There are a few infelicities in the (American) English, but I only found three typos: on p. 52, four lines from the foot, Royal Society should be Royal Astronomical Society (the famous Chandrasekhar–Eddington disagreement occurred at a meeting of the RAS), on p. 101, line 2, 'Causal' should be 'Casual', and on p. 103, section 6.31 line 1, Martin should be Maarten. A Glossary will help the general reader and there is a useful index (although it doesn't include people's names). There are no references to any of the original work. — Robert Connon Smith.

Introduction to General Relativity and Cosmology, by Ian R. Kenyon (IoP Publishing), 2023. Pp. 307, 26 × 18·5 cm. Price £75/$120 (hardbound; ISBN 978 0 7503 3761 8).

General Relativity is more than 100 years old, and the number of GR textbooks about it probably exceeds 100, beginning with Einstein himself (1920, *Relativity, the Special and General Theory*, translated by Robert W. Lawson from *Uber die spezielle und die allgemeine Relativitätstheorie*) and Arthur S. Eddington (1920, *Space, Time, Gravitation*). The midpoint from then to now is marked by the massive *Gravitation* by Charles W. Misner, Kip S. Thorne, and John Archibald Wheeler (otherwise known as *MTW*). Steven Weinberg entered the fray in 1972 with *Gravitation and Cosmology*, a portent of things to come.

The present volume is a second edition of a 1990 (Oxford University Press) original, very much updated to include gravitational waves, the *Event Horizon Telescope*, and especially cosmology, including the use of Type Ia supernovae to demonstrate the acceleration of cosmic expansion. It is one of five recent texts increasingly weighing down my desk, as part of a quest for a text for an undergraduate major course on General Relativity and black holes for winter quarter 2024. All share a much larger fraction of pages devoted to cosmology, including inflation, details of the CMB, Big Bang nucleosynthesis, and structure formation than is present in the earlier volumes.

Kenyon devoted eight of his 17 chapters to these issues, *versus* four of 44 in *MTW*, one-seventh of one chapter out of nine in Joseph Weber's 1961 *General Relativity and Gravitational Waves*, three of 24 chapters in James B. Hartle's 2003 *Gravity: An Introduction to Einstein's General Relativity*, and, for that matter, three brief sections out of 32 (called 'Considerations on the Universe as a Whole') in Einstein's 1920 monograph. The explosion of cosmology has made most of these volumes too long for a 10-week quarter, or even a 15-week semester, despite sometimes leaving out the classic tests of gravitational redshift, light bending by the Sun, and advance of the perihelion of Mercury (all considered by Einstein). These have the advantage of being reasonably easy to understand. Kenyon includes Mercury and light bending in a chapter with the Shapiro time delay, geodetic precession and frame dragging, and gravitational lensing.

He attempts some history, crediting John Michell in 1787 with the first suggestion that large GM/R can mean an escape speed larger than the speed of light. A similar conclusion by Pierre-Simon de Laplace in 1795 does not appear. The binary pulsar 1913+16 appears as a graph of period change from the time of its discovery up to approximately 2013. The data are perfectly fit by a general-relativistic prediction of energy lost in gravitational radiation. Each chapter has half a dozen or so exercises, including distortion of a human too close to a black hole and calculation of the flux of gravitational-wave energy from the binary pulsar to be expected here in Irvine

That flux would be very similar in Birmingham, where the author was a member of the particle-physics group for more than 50 years. The present head of that group, Paul Newman, is thanked in the author's acknowledgements, but is, in turn, the writer of a short tribute to author Kenyon, who sadly died while the book was in the final stages of production. Kenyon was also the author of undergraduate textbooks on particle physics, classical and quantum optics, and quantum physics under the title of *Quantum 20/20*. Kenyon's view of dark energy is that it is a scalar field that behaves, in most respects, like Einstein's cosmological constant. He sounded less sure about inflation being the manifestation of another scalar field.

Oh. Am I supposed to tell you which tome I have adopted for Physics 116 here at UC Irvine? Naturally, the one that Kip Thorne told me is the best General Relativity text ever written. No, not *MTW*. Hartle's *Gravity*. —Virginia Trimble.

To the Stars: Women Spacefarer's Legacy, by Umberto Cavallaro (Springer) 2023. Pp. 594, 23·5 × 14·5 cm. Price £34·99 (paperback; ISBN 978 3 031 19859 5).

Here are 75 women cosmonauts, astronauts, taikonauts, and possibly other designations for those who have flown well above the Earth's atmosphere between 1963 and 2022. At least a few are, or have been, national heroines — Valentina Vladimirovna Tereshkova (born 1937) in Russia and the Soviet Union; Sally Kristen Ride (1951–2013) in the United States; and (I hope) Helen Patricia 'Lenochka' Sharman (born in Sheffield in 1963) in Britain, though she flew on a Soyuz mission (TM-12). The volume is chock full of firsts, some by nation (Liu Yang the first female taikonaut, Chiaki Mokui of Japan, Yi So-Yeon of Korea, on to Anousheh Ansari, the first Iranian spacewoman, again on a Soyuz (TNA-0)).

Others are first mother in space, first teacher, first actress, first EVA (Extra-Vehicular Activity) by a woman, the first astronaut's daughter in space (Laura Shepherd Churchley), not to mention other extremes like Wally Funk at age 82 on *Blue Origin NS-16*, the oldest person to fly, 60 years after she had been the youngest of the *Mercury 13* women who were briefly tested and trained by NASA but never flew.

The author gives his affiliation as the Italian Astrophilately Society in Torino and here demonstrates his passion for stamps showing astronauts by illustrating his short biographies with images of 'first day cancellations' of most of the women featured. Sally Ride, who appears on stamps of 13 different countries, was herself a collector, whose personal stamp collection was donated by her surviving partner, Tam O'Shaughnessy, to the National Postal Museum in Washington, DC.

Every one of the capsule stories has a 'gee whiz' item. One woman played her flute on the *International Space Station*; another later headed NASA's Astronaut Office. Elena Kardakova was born the year of the *Sputnik* launch. The youngest American astronaut to date (Hayley Arceneaux) is a cancer survivor who flew with a prosthetic limb. Kathryn Thornton (and Story Musgrove) were the first civilians assigned to a military Shuttle flight (they launched an ELINT). MD Bonnie Bondar has received 24 honorary doctorates from Canadian and American universities. Ellen Ochoa, born in Los Angeles the year NASA was established, is living proof that it is better to be a professional electrical engineer and an amateur classical flautist than the other way around, and has served as Director (the 11th) of the Johnson Space Flight Center in Houston, Texas.

Nearly every page has a purple mark — not for errors (I have done no fact-checking) but for "ah ha!" moments — one of the women was a Girl Scout (no luck checking which one: the index is very sparse); another attended a high school that shared its name, Sidney Lanier (also not indexed), with the local public library of my childhood (both have probably been renamed). There really were icicles on the launch tower the day Judy Resnik (the first Jewish woman to fly) took off for the second, devastatingly brief, time. Karen Nyberg was the first astronaut to operate all three robotic arms on the Shuttle, and she also enjoys quilting, and made a dinosaur toy for her son out of Russian velcro-like fabric that lined their food containers. Megan McArthur celebrated her 50th birthday in space, the zeroth having been celebrated in Honolulu, because her father was a career naval officer.

Appendices list all the women, in chronological order by first flight (Tereshkova, Savitskaya, Ride, Resnik, McAuliffe…on to Mae Jamison (the first female African–American astronaut) and Elena Kondakova (third Russian woman, who appears in Appendix IV because of being married to another cosmonaut)), and on to the last eight, nearly all on commercial flights, beginning with Beth Moses. The other appendices list female EVAs (the longest 60 hours in ten separate activities by Peggy Wilson); astronauts with military affiliations; astronaut marriages and a good many divorces.

All in all a fascinating book, which is probably best read a few stories at a time, like consuming a large box of candy of many different flavours.

Of the women, I knew only Sally Ride, having met her when she was still a graduate student at Stanford, and then having served on her advisory board when she was running the California Space Institute (CalSpace) from UC San Diego. — Virginia Trimble.

Quantum Processes & Measurement. Theory & Experiment, by Claude Fabre (Cambridge University Press), 2023. Pp. 303, 26 × 18·5 cm. Price £49·99/$64·99 (hardbound; ISBN 978 1 108 47777 2).

We are rapidly approaching the centenary of the first papers on what is now called quantum mechanics, and the number of published textbooks on the subject must certainly also be close to 100. Early ones often emphasized puzzling aspects of the subject — that a careful calculation never gave an exact result for the product of a well-defined particle collision, for instance, but only the distribution of probabilities over the range of possible final states. Most of the later texts (at least in English) have been of the 'shut up and calculate' variety. Author Fabre takes a third approach, beginning with recent experiments that involve the detection of single quantum entities, photons, particles, and energy levels of an atom. Subsequent chapters alternate between theory (especially as required to understand recent experiments — entanglement and all) and those experiments. The experiments end with SQUIDs and the theory with quantum non-demolition.

The last 100 pages include 11 appendices, from qubits to quantum mechanics of electrical circuits, 187 references (from Aaronson to Zurek), and the usual inadequate 2¼-page index characteristic of physics texts. Each chapter and each appendix ends with exercises, some requiring serious derivations; others inviting the reader to attempt an order-of-magnitude estimate of some quantity she had probably never thought of before. She will, however, find lots of old friends in the list of references: Aharonov and Bohm, Bell, Bohr, and Born, Hanbury Brown and Twiss, Dirac, Podolsky, and Rosen, Landau (looking lonely without his Lifshitz), Planck, Robertson, and Schrödinger, von Neumann and Wigner.

Alice and Bob appear scattered through the text, though neither seems to be an author or an index entry.

Astronomers are obviously not the primary readership for this volume as we hardly ever encounter single atoms, let alone rubidium in $n = 49$ to 54 levels. It is, however, surely good for the soul to be reminded from time to time that there is a distinction between things nobody understands (the ratio of electromagnetic to gravitational forces) and things that other people understand and I do not! — Virginia Trimble.

From The Library

Suns and Worlds, by W. H. (William Herbert) Steavenson (A & C Black Ltd.), 1933. Pp. 104, 18 × 12 cm. Price about $25 for used copy from an on-line bookseller. (hardbound; no ISBN).

W. H. Stevenson (1894–1975) was a medical doctor, variously called Dr. Steave, Steave, and Old Steave (that last by Raymond Arthur Lyttleton) with a life-long love of visual astronomical observing with small-to-moderate-sized telescopes, some of his own design. Rather remarkably, he did this with only his left eye, the right one having been lost in a boyhood accident, and he abandoned observing at the age of 60 (1956), though he lived nearly another 20 years and participated in both RAS and the British Astronomical Association in his later years.

Dr. Steavenson's ADS publications come mostly from the *Journal of the BAA* and include many annual reports from his observatory in Norwood, but also this book. *Suns and Worlds: An Introduction to Astronomy* is a wonder of glorious English prose of a style I fear no one still knows how to write. Some sentences are quite long, but every word counts, is in the right place, and sometimes clarifies in a way that might easily have taken another whole sentence.

My copy once belonged to the Reverend R. Lacey Webb, who did not turn up in a very casual web search. The copy came with two bonus loose pieces of paper: a 28/11/71 clipping from the *Sunday Express* headlined "So maybe there is life on Mars", reporting water vapour seen in the Martian atmosphere from *Mariner 9*; and a handwritten page of notes on Earth, Pluto, Mercury, and the Sun taken from the *Readers Digest World Almanac*. Written with a fountain pen in a rather old-fashioned spikey hand, the extract claims that the Sun has a central temperature of 36 million degrees C and an estimated survival of 16 000 million years. These are, to our minds, too large by factors of about 2 and 3, respectively. But we must not blame Dr. Steave for the mistakes.

What then did Dr. Steave have to say? He is very sound on day and night, eclipses, motions of planets, and the like, giving the objects concerned personal pronouns (*She* for the Moon and Venus; *He* for the Sun and the other planets). We are told that use of Eros to get the length of the AU has replaced transits of Venus, which no one will again attempt to observe. Well, we did for the most recent pair, but not to determine the length of the AU!

Skipping to 'A Boundless Universe' at the end, he accepts that the Universe is expanding, and that indeed some mathematicians had expected this. He worries that the expansion time-scale is much shorter than the time needed for stars to form and achieve their various current appearances. Nowhere, however, does he attempt to estimate ages or life expectancies for the Sun or any other stars. There is an evolutionary scenario laid out in 'Other Suns' and 'Change and Motion in the Universe', but no time-scale at all.

The evolutionary scenario is essentially H. N. Russell's 'Giant and Dwarf Theory' (stars condense, heat up, move across the H–R diagram from right to left as giants, then descend diagonally down the main sequence to end as red dwarfs and, eventually, dark stars, though a few are allowed to reheat and become white dwarfs. All the stars and indeed all cosmic objects are averred to be made of the same substances, though the only entity mentioned as being dominated by hydrogen is the solar corona.

No credits are given for the rather nice photographs and drawings, which are therefore probably the author's own. His Milky Way is roughly that of Shapley, a disc with the Solar System far from the centre, but the disc is made of star clusters (we live in the local one), and our Galactic core has been largely denuded in forming stars that now occupy the spiral arms. That is, his picture of galaxy evolution endorses the vocabulary of 'early' (elliptical) and 'late' (spiral) types, just as his picture of stellar evolution endorses 'early' and 'late' spectral types. The Milky Way indeed has a flock of globular clusters above and below its plane (so does the Andromeda nebula), though they are not concentrated toward the centre and do not extend as far out as the edge of the disc.

In a bit of healthy scepticism, Steavenson suggests that it may not be true that other galaxies are much smaller than the Milky Way (indeed, modernized distance scales have taken care of that, as well as of the time-scale problem). His Milky Way rotates, at about 200 miles per second where we are (yes, miles, also inches, light years, and so forth), yielding a mass of about 100 000 million suns.

According to the received wisdom of 2023, Dr. Steave is very sound on the nearby (indeed he mentions two asteroids that come closer than Eros, though they were found in 1932 and did not yet have orbits as he wrote) and remarkably both accepting and sceptical of 1933 views of "the boundless universe." The parts we want to rewrite come in the middle!

Perhaps also odd by our standards are the author's choices of which astronomers to mention by name — Copernicus, Kepler, Tycho, Newton, William Herschel, and Galileo (in that order) — and none of his immediate predecessors or contemporaries, or looming successors. This probably saved him from making enemies — as indeed reflected in his election to the presidency of both the BAA and the RAS.

In summary, a lovely 90-minute read with two bonus pieces of paper (you would be surprised at the prices for nightgowns in 1971!) and a mysterious former owner. — VIRGINIA TRIMBLE.

Here and There

ALSO THE INVENTOR OF A TIME MACHINE

October 7: Death of Thomas Frederick Furber. Born in England in 1955 he was an Australian government surveyor of New South Wales; observed the Transit of Venus in 1882 from Lord Howe Island; FRAS 1896. — *The Observatory*, **143**, 283, 2023. [For which the Editors are guilty.]