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REVIEWS

General Post-Newtonian Orbital Effects. From Earth's Satellites to the Galactic Centre, by Lorenzo Iorio (Cambridge University Press), 2025. Pp. 282, 25 × 17·5 cm. Price £125/$160 (hardbound; ISBN 978 1 009 56287 4).

The title of this book neatly summarizes both it and many of the author's numerous papers, which have made his name well known. The book deals with many subtle issues which can, in principle, be examined by careful perturbative analysis of two-body motions in the Universe. Thus it is packed with formulae providing the effects on orbital elements (mainly) of perturbations from a wide variety of sources. Actually, while 'post-Newtonian' might to many readers mean 'relativistic' or, more widely, non-classical, the book actually also includes quite classical topics, such as the J2 perturbation of an oblate body, though these are often included as nuisance terms which, if omitted, might mimic the non-Newtonian effects of interest. Little is said of the effects of gravitational waves.

The kinds of effects under discussion are divided into about eight chapters, dealing separately with first- and second-order effects, gravitoelectric and gravitomagnetic relativistic effects, perturbations in non-standard dynamical theories, and so on. Each one of these chapters begins with a short introduction to the physical context of the effects covered, and, having only a nodding acquaintance with some of them myself, I found these interesting. That apart, the text is full of formulae, usually with no more than outline derivations, which the reader has to fill out from the cited literature or provide for himself. The references to the literature are apparently very comprehensive, and the citations and the formulae themselves are presented with a lot of care; the longest ones are hived off to separate appendices.

The author's main application of such results is observational, but almost nothing is said of the statistical methods which such work requires. He does, however, point out the danger of searching for an effect by fitting the residuals from an existing incomplete theory, if one does not repeat the entire fitting with the augmented theory. And when no natural binary motion exists for examining some effect, it can sometimes be done with a suitably designed probe. Some of these are described in a separate chapter at the end, and include proposals with amusingly quirky names, including IORIO (In-Orbit Relativity Iupiter [*sic*] Observatory). The entire text is lightened with etymological and other notes. — Douglas C. Heggie.

Hidden in the Heavens. How the Kepler Mission's Quest For New Planets Changed How We View Our Own, by Jason Steffen (Princeton University Press), 2024. Pp. 253, 24·5 × 16·5 cm. Price £25/$29·95 (hardbound; ISBN 978 0 691 24248 4).

This fascinating book tells the story of *Kepler*, one of the most significant space-science missions ever launched. It is a tale of imagination, innovation, perseverance, technological wizardry, and human ingenuity, described in graphic detail by one of the members of the science team who made the mission such a resounding success.

Until the 1990s, the only family of planets available for astronomers to study was our own Solar System, populated by nine planets (now eight, after the demotion of Pluto), hundreds of satellites, and countless chunks of icy or rocky debris. There seemed little reason to expect any other planetary systems — if they existed — to be very different. Then, in 1992, the first planets confirmed to exist beyond our Solar System were discovered in orbit around a dense, dying star — a pulsar. Three years later, a planet (51 Peg b) was found in orbit around a distant, Sun-like star for the first time. Furthermore, 51 Peg b turned out to be something most unexpected — a searingly hot gas giant that circled its star once every four days, the first example of what came to be known as a 'hot Jupiter'. According to the theories of the time, such a world should not exist. In the years that followed, a steady stream of exoplanet discoveries was recorded, but progress was very slow. However, a group of scientists, led by William Borucki of NASA's Ames Research Center, envisaged a revolutionary space observatory, equipped with a highly sensitive photometer, that would be able to study minute changes in brightness caused by planets transiting in front of distant stars. After years of trying to convince NASA that such a mission was viable, the *Kepler* planet-finding mission was given the go-ahead in 2001 December.

Kepler's primary objective was to spend up to four years staring at more than 100 000 pre-selected stars in order to detect variations in light with an accuracy of 20 parts per million. So much data came pouring in that the science analysts were in danger of being swamped, but the introduction of computer simulations helped to speed up the process. Today, more than 5800 exoplanets have been confirmed, and about half of these were discovered by the *Kepler* team. Jason Steffen, recruited to the *Kepler* science team before it was launched in 2009, gives a compelling account of this groundbreaking mission, including how the mission was conceived, the success of the primary mission that was cut short after four years by a hardware malfunction, and the redesign of the mission (dubbed K2) so that it was able to continue until 2018. He also describes the remarkable variety of worlds that *Kepler* brought to light, including the first super-Earths and sub-Neptunes, the first Earth-sized planets in the habitable zones of their stars, the first planets orbiting in a binary system, systems with seven and eight planets, and astrometric observations that enabled unprecedented photometric studies of numerous stars. The remarkable conclusions are that there are more planets than stars in the Milky Way galaxy, and that many of these worlds are comparable in size to our Earth. Perhaps we are not alone after all! — Peter Bond.

Starbound, by Ed Regis (Cambridge University Press), 2025. Pp. 240, 22·5 × 14·5 cm. Price £25/$29·95 (hardbound; ISBN 978 1 009 45759 0).

There are several versions of a painting under various titles commonly known as *The Fall of Icarus*. The painting, possibly by the Flemish painter Pieter Bruegel (the elder) from perhaps around 1558, shows a coastal landscape in which a horse-drawn plough is guided by a farmer across a field. In the middle distance, in the sea beyond the farm, Icarus, his wings having disintegrated, plunges to his death. Only his flailing legs are visible in the large splash. The farmer doesn't notice. The painting is said to be an allegory about both the dangers of excess ambition and the security to be had from humble toil. The story of Icarus and his father Daedalus, the maker of the wings, is said to originate with the Roman poet Ovid — the dream to fly is very old, and to fly to the stars is a desire possibly as old as humanity itself. In other versions of the Icarus painting the fate of Daedalus is also depicted; he is seen to have continued his flight to land safely on the shore.

Ed Regis is a thoughtful and amusing commentator but his exasperation with wilder extrapolations from reality seems to increase through the 12 chapters of this book, and by the last he has had enough and reveals his inner dream-shattering grouch. But it is in one of the early chapters about three 'Icons of Star Travel' that he lays out his stall. Describing the Bernal sphere, the Bussard Interstellar Ramjet, and Project Daedalus thus: "... each concept was a blend of unrealistic assumptions about what was possible or practical in an indefinite future", which he believes reflects the view that since an object had a name it also has an existence, even though "none of the designs obeyed general principles of standard engineering practice".

We need not trouble ourselves with the details of those projects to see clearly what Regis thinks is important about most of the schemes and plans to deliver humanity to the stars. He would like to see some standard engineering practice, and indeed some real existing physical objects. In 12 chapters he carefully unpicks and assesses the stories and the technology of proposed interstellar travel. He begins by leading us through the origins of the dream — and to be clear the dream is for the transport of humans to a suitable Earth-like planet in orbit around a star other than the Sun. He is not discussing manned excursions to Solar System locations: Mars, Europa, or wherever. The subject of discussion in this book is interstellar starships. Regis takes in turn each of the proposed engineering and social topics involved in the project and applies a healthy dose of reality. For example, simply pointing out that the stars are actually very far away and that human lifespans are comparatively short, makes the proposed task very difficult. To reach the nearest stars at 4·5 light-years distant using something like current propulsion technology would require thousands of years. Enhancing the technology by some means to approach around a tenth of the speed of light, using chemical energy sources, would require more chemical energy than is available on the entire Earth.

With such plain-speaking factual information, garnered from numerous sources, Regis addresses propulsion systems from the almost near-future fusion reactors to drives powered by multiple nuclear explosions, to Earth-based lasers pushing distant space sails, to far-future ideas of space warping and antimatter drives. All fail either to deliver the necessary drive or require the development of solar-system-scale fabrication capabilities. At the end of each topic chapter Regis tries to be positive and says something along the lines of "let's assume that in the future such a system becomes possible" what then? Because individual human life is short he examines the potential for gigantic interstellar spacecraft containing perhaps thousands of travellers on multigenerational voyages. He discusses the morality of such a trip where only the first generation are volunteers. Are the crew on such a ship, particularly second-generation crew, in any worse situation than the current population of the Earth by being on board a sphere enclosed in a life-support system travelling through space with no possibility of escape?

Crew psychology is tricky and has been examined, with far fewer numbers than proposed for a starship, in the self-sustaining, enclosed experimental conditions of *Biosphere 2.0* in Arizona in the 1990s. Over the two years of the project, factions quickly emerged among the eight participants — exacerbated by lack of food and low oxygen levels, both clothes and tempers became frayed. All such crew problems could in principle be neatly circumvented if the crew were asleep, placed into hibernation or suspended animation during the voyage. Long-duration hibernation has not been experimentally verified and problems abound — not least the continued growth of hair and fingernails during sleep.

As well as the host of technical problem associated with interstellar star ships there remains the overriding question — "Why Go?". Regis addresses this in his usual direct manner. He requires logical, rational answers to this challenge, which, even if the voyage is planned to take place a couple of thousand years or so in the future, would still require an unbelievably vast expenditure of resources. What benefit would it be to mankind to go wandering among the stars? Well, the obvious answer is that at some time in the future the Sun will expand and die and in the process incinerate all the planets at least as far out as Mars. Earth and humanity will be no more. But this is billions of years in the future and not one species of Earth-based complex life has lasted more than a small fraction of that time, a few hundred-million years at most. Humans with their uniquely susceptible, almost uniformly identical, DNA are more likely than most to face earlier rather than later extinction. Many commentators think it unlikely that we will last the next 1000 years. The usual answers that are given to the 'why go' question involve poetic feelings of the sort 'our future lies in the stars' or 'exploring is human nature, it is in our DNA'. Regis quite reasonably points out that the vast majority of people do not go exploring but quite contentedly sit on the sofa drinking beer and eating crisps — so it is clearly not a universal component of our DNA. The technocrats answer that a far-reaching technical endeavour such as a multigenerational starship will provide focus to such lives — a focus for human ambition. Well maybe, but again Regis notes that there are equally ambitious projects like universal health care, clean water, or contented fruitful lives for most of the Earth's human population which are also capable of providing focus and with a much more likely chance of success.

The British journalist and political commentator Marina Hyde describes a rhetorical technique used to oppose any piece of proposed government legislation or planning — a technique she calls "Whataboutery". Whataboutery describes an argument which highlights, and places penny-pinching obstacles, real or imagined, in the path that may inhibit the smooth acceptance of the proposal. "What about the financial markets?", "What about the housing stock?", "What about the farmers?". Whataboutery is particularly effective against the more ambitious proposals — what about the parking, for example, when discussing the development of a major power station. Whataboutery appears wise and thoughtful without the effort of having to argue an alternative approach, merely to point out potential difficulties. But Regis is not indulging in Whataboutery, or necessarily criticising ambition, but simply pointing out some hard facts. His discussion is not in the minutiae of small details but addresses the overwhelmingly vast lack of potentially capable technology.

The science-fiction writer Kurt Vonnegut says of *The Star Spangled Banner* that in a Universe of a gazillion civilisations no other has chosen an anthem of "gibberish sprinkled with question marks". Gibberish or not, to loyal patriots the song is inspiring and deeply meaningful. Poetry and dreams matter. As Ed Regis points out in the preface to this book, dreams have been responsible for scientific breakthroughs — he quotes the example of Kekulé and the structure of the benzene ring. There is a Flemish proverb, perhaps in relation to Bruegel's painting "and still the farmer ploughs" — perhaps we could add to that "and while he ploughs he dreams".

Perhaps the choice isn't necessarily between the hubris of ambition or the humility of the *status quo*, there is a middle way, as Daedalus discovered, to use tried-and-tested and carefully calibrated technology within the bounds of its capabilities. This excellent and thoroughly readable book guides our thinking and starship imaginings to follow Regis's ideal of not letting our dreams outrun what is possible and as he says, and delivers, in the final chapter: "What is needed is a severe and sober calculation of the odds". — Barry Kent.

Target Earth, by Govert Schilling (translated by Marilyn Hedges) (MIT Press), 2025. Pp. 120, 21 × 14 cm. Price $21·95 (about £17) (hardbound; ISBN 978 0 262 55134 2).

There is a story that Eric Clapton was given his first guitar, a metal-strung acoustic, at a very early age — perhaps five or seven years old. It had a particularly high action and the metal strings hurt his young fingers so he found it difficult to play and he gave up. Later and a bit older he tried again with a different guitar and the rest is musical legend. Many people have also given up playing music when their first instrument has been difficult and perhaps badly made. In spite of the lyrics by one-time Bristol-based singer Fred 'Leadbelly' Wedlock who claimed to have made his name singing "the folk tradition" — "With a yard of Spanish plywood and a capo" — a poor introductory instrument can be off-putting. I imagine there are generations of budding astronomers who have also been dissuaded by poor-quality beginner telescopes. Beginners' instruments and beginners' introductory books need to be of sufficient quality that they do not discourage, but rather inspire learning while also being affordable so that the cost is not off-putting.

This book is not a detailed study of asteroids, comets, *etc.*, but rather a fast-paced romp through all such pieces of naturally occurring space debris that may come crashing down on Earth. As Schilling himself says "this slim book is not the place to discuss at length all the newest knowledge" — he was describing knowledge of the Solar System's origins in that sentence — but it applies generally to the entire book. This book is not a scientific treatise but a brisk scamper through the headline information about falling space rocks. I should also say that it is very comprehensive in that it addresses most of the issues and is certainly bang up to date. It is in that, not necessarily pejorative, sense that the book may be described as superficial. In just 96 pages of text Schilling describes the objects that have struck the Earth with minor or severe consequences. He lists the sizes, composition, and impact velocity of these objects and also describes their potential sources and possible disaster-mitigating actions.

Although there is certainly a place for this low-in-detail but all-encompassing account, it is a pity that Schilling doesn't help the more inquisitive reader by adding more references to the bits of space gossip that he uses. There are a few references scattered through the text, the odd web page, a list of six other books for further reading, and there is a brief index. Few of the named space rocks are included in it. I did find interesting and surprising pieces of information in the text, such as the eight-yard-diameter rock $2020VT_4$ which zoomed between the surface of the Earth and the *ISS* in 2020 November, or that *Philae,* the *Rosetta* lander investigating Comet Churyumov–Gerasimenko, lasted a few months after its unplanned hopping over the comet's surface and crashing under a cliff face. The existence of the *ATLAS* last-alert telescope system which spots potentially hazardous asteroids was also new information to me.

There is no doubt that Schilling provides a very clear account of the real hazards of space rocks to human civilisation and the measures being taken to guard against the consequence of impact — which in an emergency might involve evacuating the population of target sites. He also outlines the benefits, for example, that our civilisations, indeed our very existence, can be attributed to the catastrophic collisions of Earth with asteroids.

My overwhelming feeling is of a book executed within time and space constraints. It seems like a rush job, as if the instructions to the author may have been to write down everything you know about asteroids in under 100 pages. The author is very well informed — so he knows a lot and thus in such limited space everything is necessarily lacking a bit of depth. To some extent this works well with his easy conversational style of writing — although some things jar. I found the use of yards to describe the sizes of meteorites as rather strange. I feel that yards are primarily used for agricultural or sports-ground dimensions — vaguely technical things are usually described in popular science in miles, feet, and inches — even when there are hundreds or thousands of feet. Yards seem particularly odd when used for the depth of a bore hole. There are also some curious sentences that are just baffling: the Antarctic meteorite hunt which is described as "success assured" — why? Or that the triceratops and tyrannosaurus demise is with "no coincidence" at a geological boundary — again why "no coincidence"? Could these be issues of translation from the original Dutch to American English or is it just that lack of a bit more explanatory detail?

To come back to my first paragraph, could this book be described as a beginners' introduction as I suspect is its aim? It is certainly well made but at just under £20 for around 100 pages of text it probably isn't great value. But does it inspire and encourage? On balance — maybe. It is full of factual snippets without much 'how' or 'why' science. This strange brew might make a great gift for a fact-loving young person — maybe one of the same age as Clapton when he finally got around to enjoying the guitar. — Barry Kent.

The Whole Truth: A Cosmologist's Reflections on the Search for Objective Reality, by P. J. E. Peebles (Princeton University Press), 2022. Pp. 264, 22·7 × 14·7 cm. Price £18·99 (paperback; ISBN 978 0 691 23137 2).

This is a 'paperback review' of a book already reviewed in hardcover; as such I mention only some things related to the physical book and some matters not mentioned by Trimble in her review[1] of the hardback version, which I intentionally did not re-read before drafting this review. Peebles of course needs no introduction, but the cover reminds the reader that he won the Nobel Prize in Physics (in 2019). Like another book[2] from the same publisher that I reviewed[3] in these pages, the first thing I noticed were the unorthodox (though different) page headings; in that book, the chapter numbers and names are at the bottom of the page; this one follows the usual convention in that respect, though the page number is in square brackets and at a fixed distance from the name of the chapter or section, rather than from the edge of the page. There is a long preface explaining the motivation for the book, no figures, more than sixteen pages of references (including article titles; unusual but useful for a book of this type are author/year references in the text), and a six-and-one-half-page small-print index; there are a few, sometimes long, footnotes in the main text.

This book covers much of the same ground as his previous book[4] (reviewed by both Trimble[5] and me[6]), though the emphasis is different, something which is sometimes explicitly mentioned (p. 166): "Let us pass over the details entered in Cosmology's Century.... We are interested in the big picture." That holds for Chapters 3–6; the first two and Chapter 7 are relevant summaries of the history and philosophy of physics from the point of view of a physicist; my guess is that most working physicists agree with Peebles when he concludes, in spite of or perhaps because of knowledge of other ideas among philosophers, that something like objective reality exists and it is the job of physicists to study it. As always, I am happy when a real scientist is critical of Kuhn's idea of paradigm shifts (pp. 30–32), which I see as at best a caricature of the way science actually works. In several recent reviews I've complained about authors who should know better getting basic concepts in cosmology wrong; I can recommend Peebles' clear and detailed explanation of the Hubble–Lemaître law (pp. 92–93). In my review[6] of *Cosmology's Century*, I wrote that Peebles only briefly mentioned the flatness problem, although he did much to popularize it[7]. There is an entire section (6.4) on that and closely related topics here, presenting, in my view, a much more balanced approach. "You win some, you lose some."

Discussion of a 'fourth neutrino' might be confusing to those who are certain that there are only three; 'neutrino' is often used in a more general sense (*e.g.*, 'effective number of neutrinos') in cosmology, and in 1977 it wasn't yet clear that there could not be a fourth generation of elementary particles. For some reason, the unit 'Volt' is always capitalized, and "fact on the ground" — a phrase which I had never encountered before — or a variant of it occurs ten times towards the end of the book. But those items are more interesting than annoying.

Of course I second Trimble's recommendation: "Please read the book." And read her review. — PHILLIP HELBIG.

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An Introduction to General Relativity and Cosmology, 2nd Edition, by Jerzy Plebański and Andrzej Krasiński (Cambridge University Press), 2024. Pp. 577, 17·5 × 24 cm. Price £69·99 (hardbound; 978 1 00 941562 0).

Both authors are well known for their highly mathematical approach to General Relativity (GR), which had a strong tradition in the former Soviet Union (Sakharov, Zel'dovich, Novikov, *et al.*) and many neighbouring countries (both authors are Polish, though the first author spent a substantial fraction of his life in Mexico). Some might quibble with the title; of the many books I've read covering both GR and cosmology, this book is both one of the longest and the most mathematical. The second author (the first died in 2005) is aware of the tension between the title and the contents, mentioning it in the preface to this second edition, and justifies calling it an 'introduction' because not all topics are covered* and because no prior knowledge of GR or differential geometry is assumed, though knowledge of calculus, Special Relativity, classical mechanics, and electrodynamics is assumed (thus one could start learning GR and cosmology with this book, though the author notes that "[it] takes a careful reader to some height of advancement"). This is very much a 'maths first' book which, despite the author's caveat, covers a large range of topics; that it also does so to a significant depth while 'showing much of the work' explains the length. The first part of eleven chapters (at only a bit more than a hundred pages) covers 'Elements of differential geometry' while the second, with thirteen chapters (but about four-hundred pages), 'The theory of gravitation'. The first part is rather standard, though it does mention Bianchi models and the Petrov classification (though that chapter, like several sections, is marked with an asterisk as being less relevant and more advanced, sort of like 'track two' in *MTW*[1]). The second part includes chapters on standard topics such as the Einstein equations, relativistic cosmology, and the Kerr and Schwarzschild

*Missing topics which are mentioned are gravitational waves, the Cauchy problem, generating new stationary-axisymmetric solutions out of known solutions, the Penrose transform, cosmic censorship, experimental tests, spinor methods, relativistic astrophysics, history of relativity, and Special Relativity.

metrics, but also topics which obviously reflect the interests of the authors, such as the Kaluza–Klein theory, Lemaître–Tolman[–Bondi] models, and Szekeres geometries; a short chapter on relativistic hydrodynamics and thermodynamics and one on the Global Positioning System are more of an attempt to include at least a brief overview of topics which are obviously important in a practical context or currently hot topics*, as opposed to more specialized topics, many of which are covered in some detail.

So it doesn't cover everything. However, it does cover a lot of ground, though of course it is necessarily restricted in the discussion of the various individual topics, about many of which books of similar length have been written. So what is the attraction of a book which covers several topics in a fair amount of detail, as opposed to a *really* introductory book then additional in-depth books for more specific topics? One possibility is that it is a good book if one wants to learn GR in some detail with applications to many fields presented in a uniform notation (different notation schemes, especially regarding signs, are a constant concern when studying GR); apart from worked examples in the main text, there are exercises at the end of most chapters (no solutions, but the last chapter is entitled 'Comments to selected exercises and calculations'). Another is that it is very well written, perhaps surprising since neither the second nor (as far as I know) the first author is a native speaker of English. (Krasiński mentions on his website that his only native language is Polish. I strongly doubt that Plebański was a native speaker of English. However, I know of an astronomer from a non-English-speaking country with a name typical for that country and who grew up there who nevertheless is a native speaker of English as well.) Indeed, the language is better than in many books written by native speakers: there are few typos, and I even have fewer complaints about style than I normally do when reading a book. Other useful features are eighteen pages of somewhat smaller-print references, including titles and the page(s) on which each is cited in the text, and a thirteen-page index (in the usual small print often used for indices). I also enjoyed the footnotes, which are often comments on the history of the topic. Occasionally, there are such remarks in the main text, or gems such as the description of the Bergmann–Wagoner theory: "... a curiosity because it is far from being well understood". From others, it is obvious that the authors are very familiar with the literature: "But this is where most textbooks make a mistake....'; "This second condition was found by Hellaby and Lake (1984), but in their paper it is hidden as two humble numbers in tables and a one-line comment and seems to have been overlooked by all later authors." There are a few black-and-white figures scattered throughout the book; except for two pictures of gravitational-lens systems, they are diagrams of the sort one expects in such books.

Some things were also a bit surprising. As mentioned, sign conventions always need to be kept in mind when studying GR, but I don't think I've ever come across Λ accelerating the expansion of the Universe when negative; when

*For example, a huge amount of work involving numerical relativistic hydrodynamical simulations has been done in order to interpret what is seen by the *Event Horizon Telescope*.

discussing cosmology in more detail, though, "[f]ollowing Friedmann we denote $\Lambda = -\lambda$".* (Note that these days, usually λ is the 'dimensionless cosmological constant' equal to $\Lambda/(3H^2)$.) Even apart from my own interest in the flatness problem, the discussion here certainly deserves special mention, starting out with a warning that "The views expressed in this section are A. K.'s. J. P. bears no responsibility for them." I basically agree with his discussion of the flatness problem itself, but instead of considering arguments claiming that it is not really a problem even within the context of the Friedmann models[6], he points out that it is "completely transformed if we consider the Lemaître–Tolman (L–T) and Szekeres models" — while that is true, it is probably irrelevant to our Universe.

Electrically charged black holes (Kerr–Newman if they are spinning, Reissner–Nordström if not) often get short shrift because they are thought to be rare. This book, though, has a fair amount of discussion on them, highlighting many interesting and unexpected (at least for me) aspects. That is true in general: although Lemaître–Tolman[–Bondi] and Szekeres models are more general than the Friedmann models usually used in discussing cosmology, it seems doubtful that they apply to our Universe, but they are discussed in great detail (not only within the context of the flatness problem as mentioned above). (To be sure, the second author has used them to try to explain the acceleration without dark energy, but I'm sure that they would have been included even if the Universe were not believed to be accelerating.) Of course, there are other topics once thought to be interesting but irrelevant — an example is redshift drift (sect. 17.10); however, due to advances in technology it can now be studied in detail[7].

Apart from the claim that one needs to know H_0 in order to measure q_0 from the magnitude–redshift relation†, I noticed no real mistakes, at least not if we can forgive the authors (both Polish, the second associated with the Copernicus Astronomical Center) for claiming that "Copernicus was the first astronomer who noted that the Earth is not at the centre of the Universe". (Copernicus is introduced in connection with the Copernican Principle that we are not located at a special place in the Universe.) However, I do think that their claim "that virtually the whole of observational cosmology is based on

*At first I thought that it was a typo rather than an unusual sign convention. Almost 30 years ago I corresponded with the late Steven Weinberg regarding a sign error in his famous textbook[2] which covers ground similar to the one reviewed here; that also involved an unexpected minus sign accompanying the cosmological constant. I sent him an email after I had convinced myself that it was actually inconsistent and not some unusual convention. We eventually found out that it was an actual typo in some printings of his book. I was surprised that he invested so much time tracking down a typo in a book written decades earlier. A few weeks ago, while listening to a seminar talk I learned that there is a more serious error in that same book, which is due to the propagation of a typo from Messiah's textbook[3]; undoubtedly many have also quoted Weinberg's expression without noticing the typo. I'm sure that that explains his dedication and attention to detail. Many years later, I reviewed[4] another[5] of his books and sent him a list of minor mistakes. Again, I was surprised about how concerned he was with them.

†While important historically[8], observational cosmology has moved beyond trying to measure only H_0 and q_0. The latter is the first non-linear term in a Taylor expansion, and thus was important when redshifts were small and distance calculation for general Friedmann models was difficult; neither is the case today.

the Friedmann–Lemaître models is a consequence of inertia in thinking and of emotional attachment to the doctrine of equivalence of all positions in the Universe" is exaggerated. Certainly a hundred years ago simple models were assumed because, with practically no data, they were as good an approximation as any and calculations are easier in them. But even before the first edition was written (2006), the idea that the Universe is homogeneous on large scales had become an observational fact (see the discussion in a book[9] by an expert in the field reviewed in these pages[10] a few years ago). Probably related to that is a sceptical attitude towards the standard ΛCDM model of the Universe and the hope of the authors that alternative explanations for the claim that acceleration has been observed might prove to be right. In another context, the authors note that one of their ideas (an attempt to explain gamma-ray bursts *via* blueshifted radiation from a non-standard Big Bang) has "met a violent opposition from astrophysically minded referees and will likely not be further pursued". There is a good discussion of the definitions of cosmological distances, but I was somewhat surprised that the simplest generalization to a more realistic universe[11,12] is not mentioned, though more complicated effects such as the position drift of light sources (due to moving matter sweeping along light rays passing through it) are.

This book has a very different balance among the various topics than that of otherwise broadly similar books. More detailed discussion of those related to our Universe can be found elsewhere, but this book is the place to go for interesting if not necessarily relevant details which are hard to find elsewhere, in addition to those reasons mentioned in the second paragraph above. After I had written this review, I came across a link[13] on Krasiński's personal web page to the review in this *Magazine* by Alan Heavens of the first edition[14]. His review is rather similar, but as expected shorter than mine. I can't improve on his recommendation: "For anyone looking for a thorough mathematical treatment of General Relativity, or for a supplement to existing books, this is highly recommended. It is not a standard text by any means, but I would be surprised if there was anyone who didn't find in it something new, interesting, and enlightening". — PHILLIP HELBIG.

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Triton and Pluto. The Long Lost Twins of Active Worlds, edited by Adrienn Luspay-Kuti & Kathleen Mandt (IoP Publishing), 2025. Pp. 292, 26 × 18·5 cm. Price £120 (hardbound; ISBN 978 0 7503 5616 9).

The icy worlds of Triton and Pluto are remarkably similar and yet their evolutionary paths have diverged. Both are technically dwarf planets and share many properties with Kuiper Belt objects. This reference book is both a synthesis of what was known about them up to and including 2023 as well as an exploration of where future studies may usefully lead. It comprises 12 chapters authored by 48 contributors, each chapter being a stand-alone account of the subject area it covers. The book is one of the latest publications in the AAS–IoP Astronomy series, which now number 59 texts, all available on-line as e-books.

The book has been edited to a high standard with relatively few errors given the complexity of some sections. Although e-books are searchable and indexable, regrettably the physical books do not have an index. There is some repetition between the various chapters — unsurprising, especially given the paucity of information available for Triton. Chapter topics include origins, interiors, cryovolcanism, morphology and geology, atmospheres and their interactions with the surface, the ionosphere and magnetosphere, and subsurface oceans (especially Triton). Three of the latter chapters deal with open questions needing answers and future measurement, but need referencing outcomes of recent decadal surveys. Interestingly, the chapter on 'Planning for Long-Lived Missions' includes human considerations and has wider relevance for the astronomical community. A cross-disciplinary chapter on the chemistry of cosmic ices of relevance to Triton and Pluto and their overlap with TNOs and comets would have been a useful addition. Currently there are no active space missions targeting Triton, Pluto, or TNOs. Hopefully this publication will serve as a focus improving the chance that a future such mission proposal will be accepted. —Richard Miles.

OBITUARY NOTICE

Sir Francis Graham-Smith FRS (*1923–2025*)

Known to his friends at the Royal Greenwich Observatory (RGO, for many years home of this *Magazine*) as Graham Smith, he was a pioneer in radio astronomy, beginning with wartime work in telecommunications — as did many in that nascent field — becoming a professor at the University of Manchester in 1964. From 1976 to 1981 he was the Director of RGO with the principal task of creating the Northern Hemisphere Observatory on La Palma in the Canary Islands. (While at Herstmonceux he enjoyed playing badminton with two of the present Editors of this *Magazine* — RWA & DJS!) He was Astronomer Royal from 1982 (ironically the post that was once held *automatically* by the head of the RGO) until 1990, but remained active in astronomy until very recently. He was born on 1923 April 25 and died peacefully on 2025 June 20. A full obituary may be expected in *Astronomy & Geophysics* since Graham was President of the RAS from 1975 to 1977.