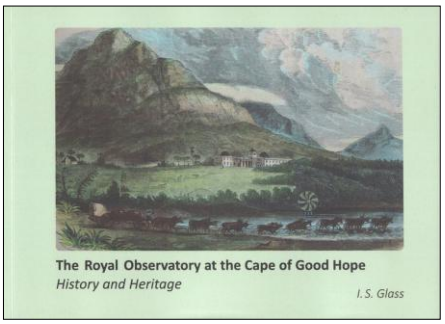
BOOK REVIEW

***The Royal Observatory at the Cape of Good Hope. History and Heritage*, by I.S. Glass. (Cape Town, Mons Mensa, 2015), pp. [ii] + 80. ISBN 978-0-9814126-2-7 (paper back), 290 × 207 mm, ~US$18.00 (see comments at the end of this review).**

When I first saw this book I immediately thought, "What a pretty cover, but is yet another book about the famous Royal Observatory at the Cape of Good Hope (henceforth 'Cape Observatory', for short) *really* warranted?" After all, I already had copies of Brian Warner's various tomes (1979; 1983; 1995) in my library.



However, Ian Glass' latest book is quite different from Brian's earlier productions: it covers the history of the Cape Observatory through to the present day, and is designed not just for astronomers (both amateur and professional) but also for those with a lay interest in South African history. As the 'blurb' on the back cover says,

> This book draws attention to a unique institution that has been part of Cape Town's heritage for nearly two centuries. The former Royal Observatory … has been the scene of several important advances in astronomy and deserves to be treasured not only for this reason but also because it is a unique architectural complex …
>
> [In this book] Emphasis has been placed on the remarkable work done there and on the extraordinary astronomers who carried it out.

And who better to write such a book than Dr Ian Glass. For much of his working life, Ian was employed by the Cape Observatory where he specialised in infrared astronomy. Fortunately for us, though, he also had a passion for astronomical history and was able to devote more and more time to this following his retirement. By my count, this is the fourth such book of his that I have had the pleasure of reviewing.

Ian relays the history of the Cape Observatory through its "… large collection of instruments and historic images …" (back cover) via an introductory chapter and six chronologically-ordered chapters. The Introduction gently reminds us that astronomical history is not just about what happened in Galileo's day or during the nineteenth century—with its giant telescopes and the emergence of astrophysics. It is also about much more recent developments, and in the case of South Africa this was the remorphing of the Cape Observatory into the South African Astronomical Observatory and the appearance of the Southern African Large Telescope (SALT), one of the world's elite 11-m class telescopes.

In just two pages, the first of the chronological chapters 'sets the astronomical scene' at the Cape prior to Britain's founding of the Royal Observatory there, mentioning in particular the French Jesuit, Guy Tachard (he was *en route* to present-day Thailand and is the subject of some of my own research), and the remarkable Nicholas-Louis de la Caille, the topic of Ian's previous book (Glass, 2013).

Chapter Three, "The Story of the Royal Observatory", introduces us to some very familiar names, including Thomas Henderson, Sir Thomas Maclear, Sir David Gill, Harold Spencer Jones and Richard Stoy. Their research and that of other staff members, including J.K.E. Halm, the Observatory's "… first real astrophysicist …" (page 18), is summarised. Also mentioned is John Herschel's sojourn at the Cape from 1834 to 1838.

The next chapter focuses on "The Buildings of the Royal Observatory", and in 28 pages Glass takes us on a tour of the various buildings that comprise the Observatory complex, with emphasis on the telescopes. Given the plethora of illustrations, this is a special treat for those of us interested in historical instruments.

"The Work of the Royal Observatory" is a 16-page chapter that not only briefly discusses the positional, photographic and photometric astronomical research conducted by staff, but also the Observatory's role as the nation's official 'time-keeper'. Personally, I enjoyed the photographs on page 48 of two of the Observatory's different time-ball towers.

The very brief penultimate chapter talks about the reorientation of the Observatory in the 1960s as an astronomical research institution, its rebirth as the South African Astronomical Observatory (SAAO) in 1972, the development of the Sutherland observing site and the acquisition of its most famous occupant, SALT. How fondly I recall the opening ceremony on 10 November 2005.

The final chapter, titled "Conservation and Heritage", not only discusses the Astronomical Museum and heritage status of the Observatory

buildings and some of the instruments, but also the natural history of the Observatory site. For example, I did not realise that

> The site is to some extent isolated from its urban surroundings by the two rivers, the Liesbeek and the Black. To the north and east are wetlands that form a sanctuary for bird life. Near its northern boundary is a bird hide that overlooks the vlei area. In winter, flamingos, geese, ducks and many other birds can be seen.

Meanwhile, the Observatory grounds still include areas of original vegetation, which boast an endangered plant and the equally-endangered Western Leopard Toad.

The Royal Observatory at the Cape of Good Hope. History and Heritage was a pleasure to read, and brought back nostalgic memories of my one and only visit there. Ian Glass writes well, and his book is a pictorial *tour de force*, with its many historical and recent photographs, cartoons, sketches, architectural plans and Observatory site maps. It is an excellent 'guide book' for those visiting the Observatory, but also deserves to grace the bookshelves of anyone with an interest in South African astronomical history. Note that the final price of copies will be determined by the cost of airmail postage to the purchaser. For enquiries and/or orders email the author (ian.glass@gmail.com) or Ms Thembela Matungwa (tm@saao.ac.za).

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Perspectives on Early Astronomy in Indian Context, by M.N. Vahia, Nisha Yadav and Srikumar Menon. (Kolkata, National Council of Science Museums, 2015), pp. [iv] + 112. Paper back, 140 × 218 mm.

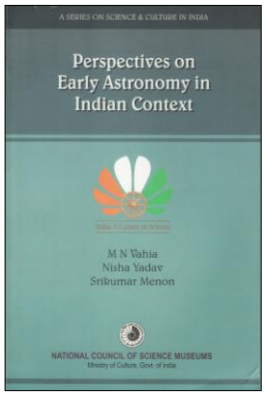
For some time I have been following the research, mainly in ethnoastronomy and archaeoastronomy, of Professor Mayank Vahia from the Tata Institute of Fundamental Research in Mumbai, so it is a great pleasure to be able to review this little book, which he wrote with two of his colleagues.

In the "Author's Note" Professor Vahia, Nisha Yadav and Srikumar Menon explain that in this book they try

> ... to summarise our perspective on how human interest in skies might have evolved.
>
> This book aims to provide a phenomenological overview of the growth of our understanding of astronomy. It does not provide technical details of how to measure locations of stars and planets or details of astronomical records in Sanskrit literature, something that has been done much better by other more competent authors. (page 3).

Following this are six chapters.

The first is titled "Evolution of Human Understanding of Astronomy". After briefly reviewing human evolution, prehistoric cultural phases and environmental change during the Pleistocene and Holocene, the authors try to answer the following question: "So how did humans gather and evolve their ideas of astronomy from the first stages of their evolution and understanding?" (page 8). In so doing, the authors look at the Sun, Earth, Moon and stars, and the seasons. While much of this is basic fare for astronomers, novices will find it useful.



The next chapter, "Astronomy in the Context of Human Intellectual Growth", largely provides a background context for the more detailed analysis of Indian astronomical history, which will follow. The authors point out that "Attempts made by humans in trying to understand the heavens are of profound interest and importance." (page 24), and they proceed to discuss the following topics: myths, the splendour of the night sky, early monumental architecture, religious ideas, and expression through art. In the process, they briefly introduce some Indian examples.

However, it is only Chapter 3, "Indian Megaliths and Astronomy", that fully immerses us in Indian astronomy. The authors stress that

> Most of the megaliths in India are found in the southern part or [*sic*] peninsula India, though there are other pockets of megalithic sites found at Vidarbha, Kumaon, Rajathan, Jharkand etc. (pages 35–36).

Specific megalithic sites we are introduced to are at Aaraga Gate, Byse, Hanamsagar, Hergal, Mumbaru, Nilaskal and Vibhutihalli, all in southern India, plus the stone circles near Nagpur in central India. Most of these meg-

alithic sites appear to have astronomical associations. Chronologically, Indian megalithic sites date between 2,500 BCE and CE 300.

After this archaeoastronomical focus the book moves forward in time and examines aspects of Indian ethnoastronomy. This occurs in Chapter 4, "Astronomical Myths of India", which begins with an analysis of the Banjaras, the Gonds and the Kolams from central India. These are among the oldest tribes of India, and were studied by Mayank Vahia and his anthropological associates. Particularly interesting are Tables 4.2 and 4.3, which compare the astronomical and meteorological perspectives of the three tribes and show that

> Most of the [astronomical] observations of the sky relates [*sic*] to the sky seen in the period close to the monsoonal season—from March till July. They seem to assume that the sky is the same at other periods or do not bother to look at the sky. This indifference to the sky is also interesting in the sense that even though visually striking, these societies do not seem to be impressed by it as a matter of curiousity. (page 58).

As the authors point out, this contrasts markedly with the situation in prehistoric southern India, where the megalithic sites reveal that there was a profound interest in astronomy. Vahia, Yadav and Menon then shift their attention to the Hindu and Jain religions, and spend the next 15 pages of this chapter recounting 'Astronomical Stories' (and verses) relating to astronomy, time and the origin of life.

The penultimate chapter in this little book is titled "Astronomy and Civilisation", and begins by identifying four different evolutionary phases in astronomy:

(1) The Initial Phase
(2) The Settlement Phase
(3) The Civilisation Phase
(4) The Technology Based Phase

Vahia, Yadav and Menon then devote the next 28 pages to explaining these, using India as their case study. In the process they spread their net widely to illustrate their scheme, snaring examples drawn from rock art, megalithic sites (with some inevitable repetition from Chapter 3), Vedic astronomy, the Harappan civilisation, 'Modern Astronomy', and so on. They emphasize that a great deal has already been published relating to Phases 2 and 4. Re the former, the *Vedanga Jyotisa*, an astronomical appendix of the *Rig Veda*, is particularly apposite. Although this interesting four-phase paradigm for astronomical evolution is developed here specifically for Indian astronomy, it has international applications and should be tested in other geographical regions.

Rounding out this book is a 2-page "Conclusion", with the following comment and challenge:

> We are sure that we have only touched rather limited perspectives of astronomy in this little book but we hope that it will instigate our readers to think of other perspectives and enjoy the journey and exploring those ideas. We have deliberately explored less-travelled avenues of thought in the hope that some of the readers may carry these ideas forward and confirm or negate them. (page 104).

After this are 8 pages of references.

All in all this is an interesting book, and the repeated reference (both here, and in the book itself) to it as a "little book" is slightly misleading. Admitedly, the cover is of modest dimensions, and the book spans a mere 116 pages, but most of these pages are jam-packed with text (rather than diagrams)—in small print—so the amount of reading and the information imparted, is by no means 'little'. Thus, the book contains many thought-provoking ideas and passages. Admittedly, I had encountered some of these previously, for much of the book's contents has appeared in earlier publications (including in this journal), but there is merit in bringing this scattered material together under one cover.

The National Council of Science Museums (of India) is to be congratulated on agreeing to publish this book. It is a free publication and so is excellent value, especially for those with an interest in Indian ethnoastronomy and/or archaeoastronomy. Copies can be ordered from: National Council of Science Museums, 33, Block - GN, Sector - V, Bidhan Nagar, Kolkata 700 091, West Bengal, India.

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***Catchers of the Light. The Forgotten Lives of the Men and Women Who First Photographed the Heavens*, by Stefan Hughes. Two Volumes (Paphos (Cyprus), ArtDeCiel Publishing, 2013), pp. [xviii] + 735, and [vi] + 736–1612 + [i]. ISBN 978-1-4675-7992-6 (hard copy), 215 × 302 mm, US$199 (e-book $39.99).**

The emergence of astrophysics during the nineteenth century is one of the great achievements of international astronomy, as spectroscopy and photography collectively revolutionised our discipline.

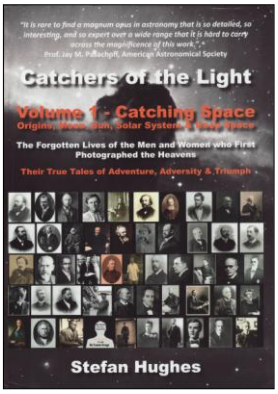
John Hearnshaw produced the classic tome on the history of astronomical spectroscopy long ago, and a second edition recently appeared (Hearnshaw, 2014), but until Stefan Hughes published *Catchers of the Light ...*, no detailed

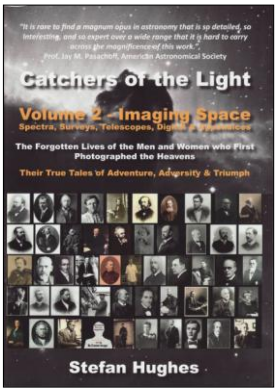
historical account of astronomical photography existed.

But to call his work a "... detailed historical account ..." is a gross understatement, for Dr Hughes has produced not one, but two massive large-format volumes totalling well over 1,600 pages, each volume chock-a-block with historical photographs.

In the front pages of the first volume Stefan Hughes speaks of the "... many thousands of hours of exertion, necessary to finish this magnum opus of Astronomy." (page v), which on the previous page he had fondly described as

> ... a '*Family History*' of Astrophotography ... [which] tells the story of the lives and achievements of the great pioneers of Astrophotography.





Volume 1 is about "Catching Space. Origins, Moon, Sun, Solar System & Deep Space", and is composed of five Parts, which deal respectively with "Firstlight", "Moonlight", "Sunlight", "Planets & Comets" and "Starlight". There are 26 chapters in these five Parts.

Volume 2 is about "Imaging Space. Spectra, Sky Surveys, Telescopes, Digital & Appendices", and is composed of four Parts, which deal respectively with "Spectra", "Cartes du Ciel", "Astrograph" and "Amateur". The 17 chapters in these four Parts are followed by 8 appendices, a list of abbreviations and an Index.

Individual chapters deal with people who were seminal either to the development of photography itself (Part I, Chapter 1) or astronomical photography, but the last chapter in each of the Parts is typically a review relating to the theme(s) of that particular Part.

The biographical chapters are very well illustrated—with many images that I have never seen reproduced previously—and end with genealogical data, followed by Acknowledgements and then Notes (sometimes pages of them, filled with amazing detail). The final chapters in each of the Parts lack the genealogies but instead include one or more summary tables, before the Acknowledgements and Notes. Thus, the final chapter in Part 1, on "Astronomical Photographic Processes & Technologies", has a 3.25-page table on "Photographic Processes Chronology", which spans the period 1800–2004 and from 1969 focuses on CCDs, while the end of Chapter IV.5 ("'Wandering Stars'. Imaging the Solar System") has a 2-page table that provides a "Solar System Photography Timeline" for the period 1851 to 1956.

Near the start of his book Stefan Hughes advises that

> The reader can choose which part to read either in sequence, in the order that takes their interest or any chapter of their choosing. They will lose nothing no matter how they read the book or in what order.
>
> [Furthermore] ... the book can be used at a number of levels; either as a biography of the lives of the pioneers of astrophotography; a source of reference for a student or researcher; and finally as a technical compendium on the historical development of photographic equipment, processes, technologies and techniques, that are relevant to Astrophotography. (page iv).

These comments highlight the fact that this massive two-volume work is more like an encyclopaedia of astronomical photography than a 'regular' textbook, and I suspect that most astronomers will use it for reference purposes as demand inspires or inspiration demands.

This is precisely what I did with Volume 1. With research interests in solar, Solar System and cometary astronomy and galactic astrophotography, I carefully read Parts II, III, IV and V (after skimming chapters in Part I), and—as expected—ran into many familiar names, including E.E. Barnard, William Cranch and George Phililps Bond, Warren De La Rue, Henry Draper, Benjamin Apthorp Gould, Paul and Prosper Henry, Jules Janssen, James Keeler, Maurice Loewy, William Pickering, Isaac Roberts and William Wilson.

In the process of reading these chapters I also encountered familiar objects and instruments, like two photographs (on pages 272 and 439) of one my favourite comets, C/1881 K1 (Tebbutt), otherwise known as the 'Great Comet of 1881' (see Orchiston, 1999). I was a little surprised, though, to see that Schaberle's 40-ft Camera was missing. This was the instrumental mainstay of the Lick Observatory's solar eclipse expeditions from 1893 onwards (Pearson et al., 2011), and during totality produced what at the time were unprecedented images of the chromosphere, prominences and the corona (see Pearson and Orchiston, 2008).

I also really enjoyed reading the Janssen chapter, and about his observations of the 1868 total solar eclipse and the 1874 transit of Venus. Since Dr Hughes researched this book, evi-

dence has emerged to show that Norman Pogson, Director of the Madras Observatory and founder of the visual magnitude scale, is the one who, during the 1868 eclipse, should be assigned most of the credit for noting an anomalous emission line in the solar spectrum that later would be associated in the laboratory with the element helium. Biman B. Nath (2013) provides details of this in his recent book.

After finishing with Volume 1, I found Volume 2 equally rewarding. Again there were chapters on very familiar astronomers, including Andrew Common, Henri Crétien, David Gill, Edwin Hubble, Sir William and Lady Huggins, Milton Humason, Ernest Mouchez, William Parsons (the 3rd Earl of Rosse), Edward C. Pickering, George W. Ritchey, Lewis Rutherfurd, Bernhard Schmidt, Angelo Secchi and Hermann mann C. Vogel, and the range of supporting photographs, sketches, maps, plans and other diagrams was impressive. When coupled with relevant entries in the *Biographical Encyclopedia of Astronomers* (Hockey et al., 2014) and Hearnshaw's (2014) authoritative tome on astrnomical spectroscopy, these chapters in *Catchers of the Light* will provide readers with a 'complete picture' of these famous astronomers.

But Volume 2 has more to offer, for there also are the informative review chapters at the ends of Parts VI–VIII ("Imaging Astronomical Spectra", "Mapping the Heavens" and "Telescopes in Astrophotography"), plus two chapters in Part IX ("Amateur"), one on "Pioneers of Amateur Astrophotography" and the other on "Modern Astrophotography". The first of these final two chapters identifies the Hungarian, Eugene von Gothard, as one of the to first to open the eyes of professional astronomers to the research potential of astronomical photography:

> On the 1st of September 1886, he obtained a photograph of the famous planetary nebula in the constellation of Lyra known as the '*Ring'* Nebula (M57). It was a remarkable photograph not only for the fact it was the first ever taken of this beautiful *'smoke ring'* in space, but more importantly it showed its 15th magnitude central star.
>
> The significance of this was not lost on all who saw Von Gothard's photograph. This star at that time could only be seen [visually] under the best conditions with only the largest of telescopes, but for it to stand out like a tiny bright torch amid the black velvet of the night sky and be revealed so easily by a mere 10-inch mirrored telescope must have caused many a missed heart beat of Observatory Directors across the world (page 1272).

In addition to his astrophotographic prowess, von Gothard also was one of those who pioneered astronomical spectroscopy and photometry (see Vincze and Jankovics, 2012).

In just 64 pages, "Modern Astrophotography", the final chapter in this amazing book, takes us from the nineteenth century, through the development of various films suitable for astronomical photography, to affordable telescopes and CCD cameras for amateurs, image-manipulation software, and electronic catalogues. This well-illustrated chapter, and the preceedng one, is mandatory reading for all current or budding amateur astrophotographers, as are Appendices A and E, on "Astrophotographic Resources" and "Charge Coupled Devices", respectively.

The other Appendices deal with "Important Astronomical Photographs", "Chemistry of Photographic Processes", "Telescope Optical Systems", "Useful Astrophotography Formulas", "A Brief Glossary of Terms" and "Astrophotographer Family Pedigrees". This last-mentioned 81-page Appendix contains photographs and genealogies that complement those found earlier in the various biographical chapters.

After 2 pages listing abbreviations used throughout the book, Volume 2 closes with a 66-page Index that will greatly help those readers who wish to find information about particular astronomers, telescopes, and even astronomical objects.

Like my colleague Jay Pasachoff, who wrote the Foreword, I am in awe of Stefan Hughes, the amount of research that went into this enormous book, and the wealth of text and images he offers readers. Although the printed version may be outside the price range of some individuals I hope that astronomical libraries worldwide will purchase this book. It is an incomparable resource, and will long remain the standard reference in this field.

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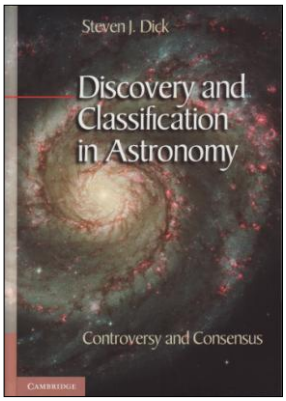
***Discovery and Classification in Astronomy*: *Controversy and Consensus*, by Steven J. Dick (New York, Cambridge University Press, 2013), pp. xviv + 458. ISBN 978-1-107-03361-0 (hard copy), 180 × 255 mm, US$45.00.**

Steve Dick, NASA's former Chief Historian, is well known for his books on astrobiology and the history of astronomy, and it is a great pleasure to see yet another book penned by him. But this one is a little different from his earlier tomes, in that it is about discovery and classification in astronomy.



As stated in the first of the front pages,

> Astronomical discovery involves more than detecting something previously unseen. The reclassification of Pluto as a dwarf planet in 2006, and the controversy it generated, shows that discovery is a complex and extended process – one comprising various stages of detection, interpretation, and understanding.

This book is composed of five Parts, titled "Entrée", "Narratives of Discovery", "Patterns of Discovery", "Drivers of Discovery" and "The Synthesis of Discovery". Each Part contains anywhere from one to four sections, that in total contain 36 short chapters.

Given the reference to the 'Pluto affair' in the first of the front pages it is fitting that Pluto's discovery as the Solar System's ninth planet in 1930, and its demotion to dwarf planet status in 2006, are the focus of the first and last chapters in Part I, "Entrée". Like, Steve Dick, I was there at the Prague General Assembly of the IAU and voted on Pluto's fate. Moreover, I was one of the rather sizable minority group that voted to retain Pluto as a planet, but when the outcome of these deliberations entered the public domain, all of us were tarred with the 'destruction of Pluto' brush and, like Steve, I too personally received abuse from members of the public and amateur astronomers. Everyone erroneously assumed that all (or almost all) of those at the Prague General Assembly wanted to demote Pluto.

Part I includes two other chapters, one about Pluto's satellite, Charon, and the other on the discovery of Kuiper Belt objects.

Part II also starts with the Solar System ("Moons, Rings, and Asteroids: Discovery in the Realm of the Planets") before examining stars and nebulae in our Galaxy ("In Herschel's Garden: Nebulous Discoveries in the Realm of the Stars", and "Dwarfs, Giants, and Planets (Again!): The Discovery of the Stars Themselves") and then "The Galaxies, Quasars, and Clusters: Discovery in the Realm of Galaxies").

In the various chapters in Parts I and II, Dick takes us on a 'Cooks' tour' of the Solar System, our Galaxy and the distant reaches of the Universe, and covers all of the key astronomical discoveries.

This astronomical focus is replaced in part in the remaining Parts of the book by philosophical themes. Thus, Part III has sections on "The Structure of Discovery", "The Varieties of Discovery" and "Discovery and Classification"; Part IV on "Technology and Theory as Drivers of Discovery"; and Part V on "Luxuriant Gardens and the Master Narrative" and "The Meaning of Discovery". Some of the chapters in these sections contain material that will be new to many historians of astronomy, and this is one of the great strengths of this book: the mixing of history of astronomy and philosophy of science. Thus.

> … we have noticed that … a discovery is not an event at a discrete moment in time … it has a structure, and this structure consists most often of detection, interpretation, and multiple stages of understanding … discovery is sometimes preceded by a "pre-discovery" phase, and (less surprisingly) is always followed by a "post-discovery" phase, both of which delimit the structure of discovery itself in both time and space. (page 177).

This is largely inspired by Thomas Kuhn's ideas, as best outlined in his well-known book, *The Structure of Scientific Revolutions*, and Steve Dick then proceeds to recount various examples drawn from the annals of astronomy.

Dick then discusses the microstructure of discovery:

> A study of the microstructure of each component would likely be even more revealing, uncovering particular forms of detection, interpretation, and understanding, as well as the problems associated with each, such as the problematic nature of observations ... Even more importantly, the conceptual elements we have emphasized so far inevitably had technological, social, and psychological components, revealing even more about the nature of discovery. (pages 190–191).

In discussing the social dimension of astronom-

ical discoveries, our old friend Pluto once again stars, followed by quasars and pulsars (and, by association, black holes). In the case of quasars, the papers by Waluska (2007) and Kellermann (2014) are particularly apposite.

In the seventh chapter, on "The Varieties of Discovery", Dick asks

> ... to what extent the telescopic discoveries differ from those made before the telescope, from discoveries of the few classes that can only be inferred indirectly by their effects, and from discoveries of new members of already established classes. (page 202).

One of the examples presented is the Great Comet of 1577 (C/1577 V1), and it is a happy coincidence that there is a paper in this very issue of *JAHH* documenting the indendent discovery of this noted comet by Abū'l Faẓl, the Prime Minister of the Mughal Emperor, Jalāl ud-Din Muḥammad Akbar (see Kapoor, 2015). In Dick's book there is then a discussion of super-novae and meteor showers, leading to

> … the following important conclusion: *casual sightings of astronomical objects with the naked eye, or telescopic observations that go unreported, unrecognized, or undistinguished as new classes of objects, constitute what we shall call a pre-discovery phase*. (page 211; his italics).

This takes us to instrument-aided indirect discovery, with cosmic rays, the solar wind and black holes presented as examples. As Dick notes, the ideas of John Michell and Pierre-Simon Laplace constitute the pre-discovery phase of black holes (Montgomery et al., 2009).

In the "Discovery of New Members of a Known Class", the detection of Mars' two moons and the rings around Jupiter, Uranus and Neptune are then cited as examples, and Pluto's discovery—as a planet—and later demotion, are also mentioned.

The last chapter in the section on "Varieties of Discovery" deals with ""Object" Discovery vs. "Phenomena" Discovery in Astronomy", on the basis that "… some of the landmark discoveries in astronomy have not been of objects, but of phenomena." (page 223). In this context, over the next 10 pages, Dick looks at three well-known phenomena: the expansion of the Universe (1920s); the accelerating Universe (1990s) and the discovery of extra-terrestrial radio emission (1930s) and later the 3° cosmic microwave background (1960s).

The final Section in Part III is about "Discovery and Classsification" and Dick points out that

> In contrast to the discovery of new laws, processes, or properties, one of the hallmarks of the discovery of localizable natural objects such as we have been discussing in this volume is an almost irresistible temptation to classify them. (page 233).

Not surprisingly, Dick begins by returning to the philosophy of science and looking at 'class' and 'classification' as used in the natural sciences, before turning to astronomy. First he focuses on the complicated issue of stellar spectroscopy, culminating in the MKK system and its subsequent MK refinements, before the focus shifts to galaxy classification, and then the place of 'class' in Solar System astronomy (with our old friend Pluto once again entering the fray). Finally, he constructs a hierarchical so-called Three Kingdom classification system for astronomy, extending from Kingdom to Family to Class, with possible extention to Type and even Subtype. This is developed fully in Appendix 2. Rounding out Part III are 6 pages on "Negotiation and Utility in Discovery and Classification", where negotiation, simplicity and utility are applied to stellar and galaxy classification.

Part IV is about "Technology and Theory as Drivers of Discovery" and begins by examining the role of optical telescopes and then the expansion of the electromagnetic spectrum to encompass radio astronomy and microwave, infrared, ultraviolet, X-ray and gamma ray astronomy. Then follow 10 pages on "Theory as Prediction and Expanation in Discovery", with Dick concluding that

> … while there may have been a general theoretical background behind many discoveries in the twentieth century, rarely did this background actually motivate discovery …
>
> The role of theory in the prediction of objects that actually led to their discovery is therefore very limited …
>
> [But] In the next stages of discovery – interpretation and understanding – theory indeed played an extremely important role. (pages 310–311).

The final Part (V) in *Discovery and Classification in Astronomy* is about "The Synthesis of Discovery". The first section, with the mysterious title "Luxuriant Gardens and the Master Narrative", begins by discussing cosmic evolution. Dick asks

> By what means, with what insights and motivations did astronomers "discover" the idea of cosmic evolution? Was it, in fact, through the synthesis of many of the discoveries addressed in this volume, or through some other more overarching principle? Does it in fact exhibit the extended structure typical of the classes it embodies, or some different structure? (page 317).

The question then emerges: is the endpoint of cosmic evolution planets, stars and galaxies (the physical Universe) or life, mind and intelli-

gence (the biological Universe)? Dick then looks at the ways in which the concept of cosmic evolution has entered the human consciousness in contemprary society, in part through the writing and television programs of the late Carl Sagan. I have no doubt that the late Sir Patrick Moore also played an important role in this regard. Consequently, the idea of cosmic evolution has been

> … interwoven into the fabric of society well beyond its scientific content … [although] The ultimate meaning of cosmic evolution is not yet apparent … (page 328).

The final chapter, on "The Meaning of Discovery", reviews the findings of the preceding 328 pages of this book by looking first at "The Natural History of Discovery" and finally at "Beyond Natural History: The Evolution of Discovery". We are warned that although the scheme presented in this book accommodates most astronomical discoveries,

> … we should take care not to shoehorn *all* discoveries into this structure … [as] *There are interesting exceptions* … [and] each of the components of discovery – detection, interpretation, and understanding – has its own *gray areas*. (pages 331–332; my italics).

Dick then discusses problems associated with the definiition of 'discovery' and sings the merits of collective discovery. Thus,

> … Galileo detected what we now know to be the rings of Saturn in 1610, Huygens interpreted them as such in 1655, and Maxwell showed how such an object could exist in theory in 1857 – a process encompassing more than two centuries. To say what is often said, that Galileo discovered the rings of Saturn, is to do violence to history, to conflate discovery beyond recognition, and to do a disservice to the beauty and complexity of science and discovery. The same may be said for other classes of astronomical objects. (page 336).

He then looks at the role played by developing technology in the occurrence and pace of discoveries, and produces Figure 11.1, a fascinating histogram that plots the number of discoveries against time for the past 450 years. This shows distinct decadal peaks that reflect Galileo's access to the telescope in 1610, William Herschel's use of large telescopes in the 1780s, and a "... mountain of discoveries in the twentieth century, three times greater than the sum of the previous 350 years." (page 338). The data used in compiling this diagram are assembled in a 23-page Appendix (number 2), at the end of the book.

Figure 11.1 automatically raises the thorny question of "Are we at the end of discovery or only the beginning, or somewhere in between?" (page 339). Different astronomers offer different answers, depending very much on how the term 'discovery' is defined. Only time will tell!

Ending the book are the two previously-mentioned appendices, 58 pages of Notes, a short "Select Bibliographical Essay", a glossary and a detailed Index.

I hope that the foregoing account imparts some of the flavour of this remarkable book. It is an intellectual banquet, but too large for most of us to consume in just one sitting. It is composed of different courses: first an introductory entrée, followed by a main course comprising historical narrative garnished with theory provided by the history of science, and then a dessert that looks at the the present and the future of astronomical discovery. It is masterfully written (as are all of Steve Dick's books), and is full of thought-provoking ideas and discussion. At just US$45.00 it is very well-priced, and should join the bookshelf of many astronomers—not just those committed to the history of astronomy.

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CORRIGENDUM

Unfortunately there is an error in the caption of Figure 4 in the following research paper, that was published in the July/August issue of this journal:

Steinicke, W., 2015. William Herschel and the 'Garnet Stars': μ Cephei and more. *Journal of Astronomical History and Heritage*, 18(2), 199–217.

The new figure caption should read:

Figure 4: Herschel's 'large 20-ft' telescope, shown here at Datchet in its original form (after Dreyer, 1912: Volume 1, Plate B).