books and papers, and there is no Index at the end of the book. However, on the brighter side, we both found Appendix 2 useful.

A book like this that incorporates astronomical and biographical material should be treasured by those interested in the history of Indian astronomy and provide them with enjoyable and, more importantly, reliable, reading. Sadly, this is not such a book, and the fact that the author is no expert on historic transits of Venus and therefore was unfamiliar with much of the relevant literature really stands out. But the publishers also are to blame, and have done a shabby job. At very least, the Kannada text and the corresponding English translation should have been placed on facing pages so as to facilitate a one-to-one match.

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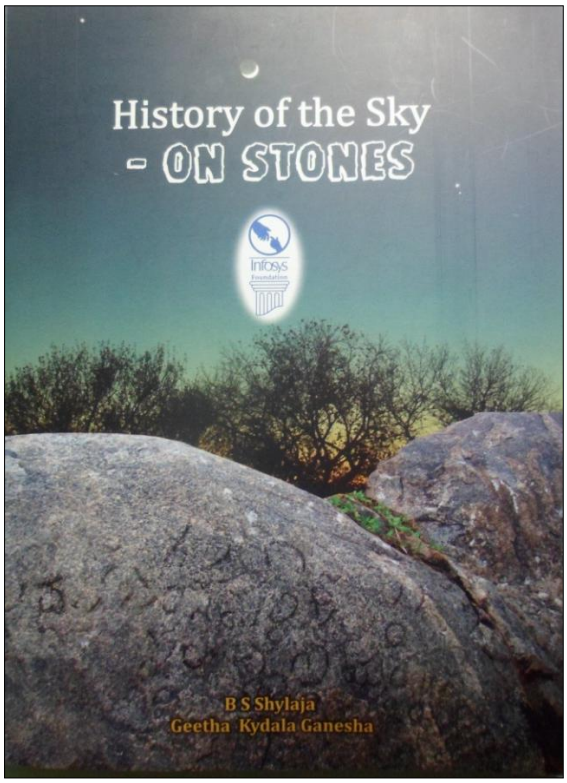
***History of the Sky – On Stones*, by B.S. Shylaja and Geetha Kydala Ganesha. (Bangalore, Infosys Foundation, 2016). Pp. 152. No ISBN listed (paperback), 180 × 240 mm, Rs 200.**

One of the distinct benefits enjoyed by those of us who attended the recent 9th International Conference on Oriental Astronomy in Pune was the concurrent appearance of new books about the history of Indian astronomy.

One of these was an attractive paperback about the invaluable information that inscriptions on stone provide about historic astronomical objects and events. As the authors point out in their Preface:

> Every village has a history; and every village has it recorded on one or several stone [sic.]. These stone inscriptions are of great importance to historians, sociologists and traditional scholars, though very little attention was paid on the study as sources of astronomical records.
>
> When we ventured to explore this new avenue to fetch unknown records of astronomical observations we did not know the volume of the task that lay ahead. (page 3).

I suspect that had the authors realised the magnitude of the task at hand they would quickly have diverted their attention to other projects, for soon they were 'drowning' in inscribed stones, where ~ 38,000 inscriptions had been recorded over the past century or more. These inscriptions date back to the third century BC, and they contain a "… wealth of information



on various aspects of evolution of culture, trade, history and region …" (page 12). Most of these have no relevance to astronomy, but those that do and are discussed by Shylaja and Ganesha in their book exceed 1,500. The stunning thing is that their study was restricted to the central part of southern India, and even there new inscriptions continue to be discovered. Imagine the plethora of data available if and when the whole Indian Subcontinent is surveyed in this way!

So what sorts of information have Shylaja and Ganesha uncovered in the course of their research? Since inscriptions normally were only engraved on special occasions, there are abundant records of solar and lunar eclipses, planetary conjunctions, and lunar occultations, and occasional references to comets. Fortunately, the dates of all of these are accurately recorded in the inscriptions, but since various dating systems were used in different parts of India during the past two millenia the inscription dates must be converted to our current 'Western' calendrical system. This challenge is outlined in Chapters 2, 3 and 4.

Solar eclipses and lunar eclipes are discussed in Chapters 5 and 6 respectively. Solar eclipses (total, annular and partial) date from AD 21 May 616 to 24 March 1849 and they are listed individually on pages 107–115. Several of these eclipses are mentioned in more than one inscription. Not all of these eclipses were in fact observed, as some of the paths of totality bypassed India. However, the authors conclude that

> In general we find that the large number of eclipse records provide a homogeneous data for verifying long term variation of parameters involved in the prediction of eclipses. (page 38).

The earliest lunar eclipse recorded on an inscription dates to AD 30 April 660, and the latest to 8 May 1876. Individual eclipses are listed on pages 116–126. A particularly interesting record dates to 14 February 1710 when the eclipsed Moon occulted Regulus (*Magha*) just before moonset at dawn.

Many planetary conjunctions are recorded on stone inscriptions, and these, and lunar occultations of stars and planets, are discussed in Chapter 8 and listed individually on pages 127–148. Some of these must have been visually-aluring events. For example: on 2 October 1117 and 22 August 1467 Saturn was in conjunction with Aldebaran (*Rohini*) and the Hyades; on 2 March 1169 the Moon, Jupiter and Mercury were in conjunction; on 10 February 1671 the Moon, Mercury and Saturn were in conjunction; and occultations of Mars by the Moon occurred on 12 December 1112 and 14 December 1132. In addition to these and other conjunctions and occultations, there also are many records of solstices and equinoxes, the earliest of which dates to AD 687.

Chapter 9 is titled "Revelations of Celestial Phenomena", and the authors claim that "Our studies of stone inscriptions have revealed quite a few new results which have escaped the attention of epigraphists", but some of their conclusions are open to debate. Thus, drawing on references to *Ketu,* they suggest that two new stars reportedly observed by Chinese astronomers on 9 and 18 December 1297 between Pisces and Andromeda can be associated with the planetary NGC 7662, on the basis that its two distinct ellipsoidal shells document eruptions 700 and 1050 years ago. Yet neither

of these dates aligns precisely with the Chinese observations, and planetary nebulae are not known for nova-like eruptions.

In Chapter 9, Shylaja and Ganesha also point out that inscriptions hold promise of identifying transits of Mercury and Venus, but although they suggest one possible transit of Mercury (21 April 1056), they were not able to assemble any convincing evidence of transits of Venus (cf. Kapoor, 2013). However, they live in hope:

> These examples offer an optimistic view: the current survey on stone inscriptions has covered only 10% of the available 30,000 (and more being added now) records centered in and around Karnataka. Hence a systematic search of such inscriptions from all over India is likely to yield more results. (page 84).

Arguably one of the most important parts of the whole book is Section 9.3, which is titled "The period of rotation of the earth". Here Shylaja and Ganesha discuss the role that accurately-dated solar eclipses have played in documenting variations in the rotation rate of the Earth, a field of study pioneered by the noted British astronomer, Professor Richard Stephenson of Durham University. Stephenson has plotted these variations (referred to as ΔT) against time (e.g. see Stephenson, 2006; 2007; 2011; Stephenson and Morrison, 1995), and in Figure 9.3 on page 87 Shylaja and Ganesha include one of his plots (erroneously referred to as a 'Soma Diagram', and published by Morrison), where eight new data points, based on dated Indian eclipses, are included. It is heartening to see India finally making a valued contribution to this important area of history of astronomy research, which is known as Applied Historical Astronomy.

While most of this book is devoted to astronomical stone inscriptions, the authors devote nearly four pages to the lifespan of Sri Rāmanujācārya, "… the great saint of the Srivaishnavaite sect, [who] has left a remarkable imprint in the whole of South India." (page 97). His birth and death dates are generally given as AD 1017 and AD 1137, and this long lifespan has generated much debate. Using data contained in inscriptions, Shylaja and Ganesha come up with a revised birth date of AD 1077, and a more realisitic lifespan of 68 years.

The final chapter in this book is titled "Expectations and realities", where the authors stress that astronomical inscriptions were not recorded because of the importance of the celestial events *per se*, but rather because their occurrence led to offerings being made. Thus

> … emphasis lay on the act of donation … and recording the donor and donee. The actual celestial event was perhaps only an excuse to perform this action ... [and get] its name immortalized on the stone inscription. (page 102).

Most of the inscriptions used in this study were already recorded earlier by others, and the challenge Shylaja and Ganesha faced was to work their way through these extensive published lists and sift out the astronomical inscriptions. In the process they encountered many unfamiliar words that had to be deciphered; some of these words were unique to the inscriptions and were not found in the general historical literature. Sometimes the inscriptions offered conflicting interpretations, but by using off-the-shelf astronomical software (e.g. Occult, or NASA eclipse web sites) they were able to resolve many of these issues. Nonetheless, many areas of India were not covered in their study, and Shylaja and Ganesha now "… are eagerly awaiting the new and revised compiled volumes [of inscriptions] to be published." (page 106).

This is an attractive-looking reasonably-priced paperback book, liberally decorated with figures, maps and tables (many in colour). I noticed very few 'typos', although in my copy of the book the last four lines of text on page 80 were duplicated at the top of page 81, and earlier on page 80 in two places Greek symbols were replaced by pairs of boxes. Apart from these anomalies, the Infosys Foundation did a good job as the publisher.

Finally, I should mention that unlike the book by Shylaja about Charry and the 1874 transit of Venus that is reviewed above by Ramesh Kapoor and me, *History of the Sky – On Stones* reveals Shylaja's true talents when she focusses on a topic she is familiar with. It is to be hoped that she and Ganesha will continue this study, and expand their analysis of astronomical inscriptions beyond central southern India. Obviously, this is a long-term project, but an important one, as it can throw valuable new light on Indian astronomy and at the same time contribute to Applied Historical Astronomy.

I feel that this interesting book marks a new era in the study of Indian astronomy, and that it deserves a place on the bookshelf of anyone with an interest in the history of Indian astronomy.

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***History of Indian Astronomy. A Handboook*, edited by K. Ramasubramanian, Aniket Sule and Mayank Vahia. (Science and Heritage Initiative Indian Institute of Technology, and Tata Institute of Fundamental Research, Mumbai, 2016). Pp. x + 662. ISBN 978-81-923111-9-7 (hard cover), 170 × 247 mm (for the price, email mnvahia@gmail.com).**

The other book received by those who attended ICOA-9 in Pune, India, in November 2016 was a handsome 672-page volume, edited by three luminaries of Indian astronomical history, Professor K. Ramasubramanian (Indian Institute of Technology), Dr Aniket Sule and Professor Mayank Vahia (both from the Tata Institute of Fundamental Research).

> As the 'blurb' on the back cover indicates,
>
> This volume is a compilation of twenty-one thematic articles that provide a glimpse of the origin and development of astronomy in India from the Vedic period till the beginning of 20th century. These articles have been contributed by a galaxy of renowned scholars.

After an introductory chapter titled "Roots of Indian astronomy" by Mayank Vahia, Nisha Yadav and Srikumar Menon where they review astronomical basics before discussing "Astronomy and civilisation" in an Indian context, the archaeologist, Riza Abbas, writes about "Rock art and astronomy in India". Those familiar with international developments in rock art studies will be aware of the challenges involved in assigning astronomical meaning to different motifs, so I was very surprised to read that Joglekar et al. (2006) have found evidence of a prehistoric supernova explosion depicted on an engraved stone slab at Burzahom, and that "In this study they have scientifically proved that this would be first record of a sky map drawn to record a particular event." (page 48). Even though I allowed the publication of a paper about this same engraving in this journal (see Iqbal et al., 2009) in order to encourage lateral thinking and discussion, in fact this engraving is controversial, and other equally-compelling interpretations can be proposed for it that have nothing whatsoever to do with a supernova.

In Chapter 3 Srikumar Menon discusses "Megalithic astronomy in India", where he stresses their relative abundance in southern India (see the distribution map on page 65). Menon concludes:

> Despite nearly two centuries of academic attention being focussed on them, the Indian megaliths still have a lot of unanswered questions centred on them ...
>
> Stone alignments in different parts of southern India and Vidarbha seem to hold some promise of astronomical sightlines incorporated as part of their design and layout. (page 81).

We then move from archaeastronomy to ethnoastronomy (Chapter 4), where Mayank Vahia and Ganesh Halkare talk about "Astronomy of tribals of central India". Although regretting the use of the term 'tribals' in lieu of 'tribes', I found this chapter interesting, although most of it was familiar to me thanks to a series of research papers that the authors had already published (and several of them in this journal). As Vahia and Halkare point out, "... several Indian tribes that have been isolated from the mainstream have their own understanding of the sky and constellations." (page 85). Over the next 11 pages or so they discuss indigenous constellations in different areas of the sky and their terrestrial associations (ecological activities, the monsoon, etc.), along with the Milky Way, Solar System objects, eclipses and creation myths. The authors hope that this chapter "... will encourage researchers in other parts of the country to undertake similar studies of the astronomy of the tribes of India before modernity completely overwhelms them." (page 104).

Then follow two chapters about Vedic astronomy, and I found the first of these, by R.N. Iyengar (Jain University, Bangalore), captivating, where he discovers references to eclipses, comets, meteorite impacts, and the shifting of the 'pole star' in Vedic texts. However, these references are not always obvious since

> ... Vedic culture personified celestial objects and their actions. Hence the texts carry a background that has to be deciphered for extracting the archaic models of the visible sky." (page 108).

As with those who wrote earlier chapters in this book, Iyengar draws on his own earlier publications, but then brings his long 63-page chapter up-to-date by including considerable new material.

Kak's much shorter chapter follows, and this presents a useful overview of the relationship

between Vedic astronomy, ritual and temple design.

Those with an interest in calendars will value Chapter 7, where two retired Indian astronomers, S.K. Chatterjee and A.K. Chakravarty discuss the "Indian calendar from post-Vedic period to 1900 CE". Their long and detailed account (49 pages) is a partly-revised version of a paper that they first published in 2000.

An old Japanese friend of mine, Dr Yukio Ohashi, is the author of the next chapter, which is titled "The mathematical and observational astronomy in traditional India". This long chapter is a reprinted version of a paper that was originally published in 2009 so was in little need of up-dating. Those with an interest in Vedic astronomy and Indian calendars also will find much of interest in this 77-page chapter, which in fact ranges beyond India to also discuss—albeit briefly—Greek, Islamic, Tibetan, Chinese and even Thailand and Burmese astronomy. Immediately prior to presenting an invaluable 9.5-page list of references, Yukio winds up his informative chapter in a charming way: "I hope some readers of my paper will become future researchers, and they will make my paper outdated by their own research works!"

In Chapter 9, M.S. Sriram, M.D. Srinivas and K. Ramasubramanian review "The traditional Indian planetary model and its revision by Nīlakaṇṭha Somayājī", while M.S. Sriram discusses "Bhāskarācārya's astronomy" in Chapter 10.

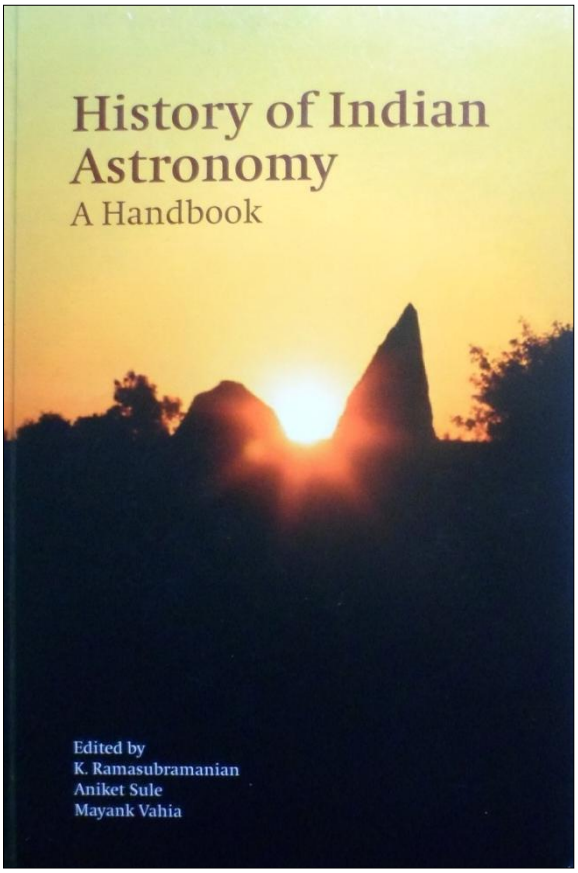
"Lunar and solar eclipse procedures in Indian astronomy" by P. Venugopal, K. Rupa and S. Balachangra Rao comprises Chapter 11 while the same authors but in revised order (Balachangra Rao, Venugopal and Rupa) discuss "Transits and occultations in Indian astronomy in the following chapter. From ca. 505 CE Indian astronomers knew the causes of solar and lunar eclipses and in Chapter 11 the circumstances of the eclipses were computed "... according to Bhāskara II's *Karaṇakutūhala*, *Grahalāghava* and Improved *Siddhāntic* procedures ISP." (page 408). Meanwhile, similar procedures were used to compute transits and occultations, but although planetary conjunctions are discussed in most traditional textbooks on Indian astronomy transits of Mercury and Venus are not explicitly mentioned. The authors therefore proceed to outline a procedure developed by Professor T.S. Kuppanna within the framework of Siddhāantic astronomy, using the 2004 and 2012 transits as examples.

The next chapter is titled "An overview of the *vākya* method of computing the longitudes of the sun and moon" and was written by Venketeswara Pai, K. Ramasubramanian, S. Srimam and M.D. Srinivas, and aims "... to highlight the ingenuity and beauty of the *vākya* method of planetary computations." (page 430).

Continuing the computational astronomy theme, Chapter 14 by Clemency Montelle (from New Zealand) and K. Ramasubramanian discuss "The numerical tables related to eclipse computation in the *Parvadvayasādhana* of Mallāri". They point out that the *Parvadvayasādhana*

> ... is somewhat unusual in the sense that it presents more complex tables having multiple rows and columns in the form of beautiful verses in *śardūlavikrīḍita* metre (19 syllables per quarter). (page 475).

The theme of the book changes notably with Chapter 15, which is about "Indian astronomical



instruments: A descriptive catalogue of extant specimens", penned by S.R. Sarma. In researching this theme, Sarma says that he

> ... decided to make a survey of museums and identify pre-modern astronomical and time-keeping instruments. Such a survey, I hoped, would be useful because the actual specimens might help in understanding the brief descriptions of the texts. Conversely, textual knowledge would help in identifying an instrument and in dating its original design. Finally, this combined approach of studying the texts together with instruments would throw better light on trans-cultural exchanges, especially between the Sanskrit and Islamic traditions of instrumentation in the medieval period. (page 478).

In the following 21 pages Sarma presents an assortment of astrolabes, celestial globes, armillary spheres, various types of quadrants, sundials, gnomons, water clocks and other rarer types of instruments of Indian design and construction. On a plaintive note Sarma describes how he made an inventory of the portable astronomical instruments at the Sawai Jai Singh Astronomical Observatory in Jaipur in 1991 and later sent his catalogue to the Observatory's Superintendent, but by the time a new building for the display of these instruments was opened the original Superintendent had retired and the instruments were displayed without proper identification. "It is like a museum displaying a painting by Picasso without any label! It is a great pity." (page 498). I totally agree with him.

The next two chapters in the book were written by B.S. Shylaja, whose name should now be well known to all, thanks to the two preceding book reviews that appear in this issue of this Journal. Chapter 16 is about "Navigation and astronomy". I presume that Shylaja's primary focus is meant to be Indian maritime navigation, but unfortunately she ranges far and wide geographically, discussing the Kerkennah fishermen of Tunisia; Gilbert and Caroline Islanders in the Pacific; Portuguese navigators; Lieutenant James Cook's use of eclipses, Jovian satellite phenomena and the 3 November 1769 transit of Mercury to determine longitude; the Bugis voyagers of Indonesia; and even the Vikings. I have to say that I found this hotchpotch of examples confusing, as much better case studies could have been employed if Shylaja's aim was simply to document the range of techniques used internationally in order to determine latitude and longitude. Then, when we finally put aside these various examples and look just at Indian navigation the pickings are lean and we end up with a rather simplistic account of how certain coastal people from the Subcontinent used astronomy to successfully sail from one place to another. However, variations in the navigational techniques and instruments used at any one time in different coastal regions of the Subcontinent are not discussed, and there is no attempt to trace changes in the techniques and technology that occurred with the passage of time. Various indigenous names for different stars listed on page 508 and 511 are not referenced, while some key references that Shylaja does mention in the text are not listed in the References section (e.g. Grimble, 1931; Leybourn, 1861 and the various papers by Vardarajan). A map of the Subcontinent and adjacent regions of the Indian Ocean would have been helpful for those readers wishing to pin down localties that Shylaja does mention. However, Shylaja seems aware of the limitations of her study when she mentions that the navigational techniques of some coastal groups have still to be studied. Furthermore, "The study hints at a vast treasure house of astronomical knowledge which is slowly being lost." (page 512), and "... satellite communication systems have now revolutionized the lifestyle in these tiny islands and are slowly wiping out the traditional techniques." Despite these caveats, and although I am vitally interested in this topic and have written on it myself (e.g. see Orchiston, 1998; 2016: Chapters 4–6), I found this to be one of the least rewarding chapters of the book.

Happily, Shylaja has made a better fist of Chapter 17, "Astronomical aspects associated with temples". Temples in India date back more than 2,000 years, and apart from their religious and educational functions some of them also were associated with time-keeping and calendar-making. After reviewing Indian calendars and festivals Shylaja transports us to South Africa, where ceremonies of reputed south Indian origin are still performed by the local inhabitants at specially-constructed places of worship. These reported south Indian-South African cultural links are fascinating and warrant critical examination. The book then returns us to India and the mathematical and astronomical knowledge exhibited by temple-builders across the subcontinent and across the sands of time. Two structures with clear astronomical associations that she reviews in considerable detail are the Vidyāśaṅkara Temple at Śṛṅgerī and the Gavi Gaṅgāhareśvara Temple at Bengalaru, although she seems unfamiliar with the paper by Kameswara Rao and Thakur (2011) about the former temple. Shylaja then discusses a number of other temples that exhibit solstice alignments, and then explores the concept of a basic scale that was used in temple construction in southern India. Leading from this is the fascinating idea that the sun temples in some cities—such as ancient Varanasi (see Rana, 2009)—were based on astronomical alignments. Shylaja stresses that her study is still in its infancy, and

> A mammoth task lies ahead — we have to decode how the blueprint of the temples were [*sic*] prepared and what were the astronomical aspects that were incorporated. (page 545).

In Chapter 18 we return to astronomical instrumentation—albeit on a gigantic scale—when N. Rathnasree (from the Nehru Planetarium) discusses "The Jantar Mantar observatories of India teaching laboratories of positional astronomy". I found it interesting that one of Jai Singh's objectives when he set up these giant masonary observatories 300 years ago was that "... common citizens could ... make observations on their own ..." (page 552) and this is precisely what Rathnasree has done as part of the outreach program of the Nehru Planetarium.

So, for the first time in 300 years, the Jantar Mantar were used successfully as a teaching laboratory, as illustrated by various photographs and graphs that accompany this chapter. After reading this interesting chapter, I now see the Jai Singh observatories in a totally new light.

The third-last and penultimate chapters in this long but invaluable book were written by Professor Raza Ansari, a long-time colleague through our mutual IAU and ICOA associations. Chapter 19 is titled "Tradition of astronomical sciences in medieval India" and was developed from a paper that Ansari published in 2014 so is totally up-to-date. After some introductory comments, Ansari discusses in sequence the major astronomical features associated with the Sultanate Period (AD 1191–1526) and the Mughul Period (1526–1748), including the contributions made by Babur, Naṣīruddīn Muḥammad Humāyūn, Abul Fatḥ Jalāluddīn Akbar, Nūruddīn Jahāngīr, Abul Muẓaffar Shahābuddīn Muḥammad Shāhjahān and Roshan Aktar Muḥammad Shāh. As Ansari points out,

> During the Mughal period, the constant stream of scholars, crafts men, and artists particularly from Central Asia continued vigorously, and those migrants brought with them knowledge of all natural sciences into India. (page 583).

In an astronomical context, this is well portrayed in this excellent, well-researched and well-referenced chapter, but one key reference that has been published since Ansari wrote this chapter is Kapoor (2015).

Nor does this high standard change in Ansari's next chapter, "Reception of modern western astronomy in the 18th–19th centuries", where

> ... we confine ourselves mainly to Persian-speaking Indian scholars, who came into direct contact with the British scientists, engineers, and doctors. These ideas resulted in an academic interaction and exchange of scientific ideas. Consequently, we present here a brief survey of selected Indo-Persian writings dealing with Modern European Astronomy ... (page 607).

Those selected for this analysis are: Sawā'i Jai Singh, Mīr Muḥammad Ḥusain, Mirzā Abū Ṭālib Khān Iṣfahānī, Ghulām Ḥusain Jaunpūrī, Raja Ratan Singh, Ḥadā'iq al-Nujūm and Tafaḍḍul Ḥusain Khān bin Ikramullāh Khān. But much of this impetus was stiffled when the British Colonial Government introduced English as the official language during the nineteenth century.

And so we arrive at the final chapter in this impressive tome, Professor Rajesh Kochhar's contribtuion on "The growth of modern astronomy in India, 1651-1960". I have known Rajesh for several decades, and have been impressed with his writings on the history of Indian astronomy, so I was rather disappointed to discover that all he chose to do was reprint a paper that originally was published in *Vistas in Astronomy* back in 1991 (and is listed in the references assembled on page 349 in these book reviews). The problem is that while the basic narrative of Indian astronomical history has not changed during this 300-yr period, much additional research has been published. So we certainly can accept Rajesh's accounts of "Use of the telescope in the 17th century", "Advent of modern astronomy in the 18th century", "Madras observatory (1786–1899)", "The great trigonometrical survey of India ...", "Lucknow observatory (1831–49)", "Trivandrum observatory (1837–52)", "Poona non-observatory", "19th century positional astronomy – a critique", "Advent of physical astronomy (1874)", "Takhtasinghji's observatory in Poona (1888–1912)", "Kodaikanal observatory (1899)", "Nizamiah observatory (1901)" and "Uttar Pradesh state observatory, Nainital (1954)", but to bring readers up-to-date the books by Launay (2012), Nath (2013) and Sen (2014) need to be consulted, while all of the following research papers contain material that supplements that presented in Kochhar's chapter: Biswas (1994; 2003); Kameswara Rao et al. (2009; 2011); Kapoor (2011; 2013; 2014); Kochhar (2002); Orchiston et al. (2006); Orchiston and Pearson (2011); Pigatto and Zanini (2001); Rathansree et al., (2012); and Reddy et al. (2007).

After Kochhar's chapter, the book ends with a 10-page glossary of astronomical terms, but there is no Index.

Notwithstanding my comments about the final chapter, and the absence of an Index, overall this is a wonderful book, with lots of interesting reading. Most of the chapters are well illustrated, and many chapters have long lists of references for those wishing to follow up specific areas of interest. I have no hesitation in recommending this book, and believe that it will long remain a primary reference work for those interested in the history of Indian astronomy.

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