Journal of Astronomical History and Heritage, 26(1), 113–158 (2023).

COLONIAL ASTRONOMY AS AN ELEMENT OF EMPIRE IN BRITISH INDIA

R.C. Kapoor
Indian Institute of Astrophysics, Koramangala, Bengaluru 560034, India.
E-mail: rckapoor@outlook.com; rck@iiap.res.in

and

Wayne Orchiston
University of Science and Technology of China, Hefei, Anhui 230026, China, and Centre for Astrophysics, University of Southern Queensland, Toowoomba, 4350, Australia.
E-mail: wayne.orchiston@gmail.com

Abstract: In this paper we outline the efforts made by the East India Company, the British colonial authorities, visiting astronomical expeditions and expatriate amateur astronomers to establish astronomical observatories in India during the three centuries prior to Indian Independence in 1947. The focus of this paper is therefore primarily on the emergence of Madras, Colaba, Calcutta, Dehra Dun, Hennessey and Kodaikanal Observatories. But we also discuss the accomplishments of the Trigonometrical Survey of India, and various total solar eclipse and 1874 transit of Venus expeditions.

The Trigonometrical Survey of India and the aforementioned observatories were primarily established to further Britain's colonial ambitions, and some of the astronomical observations were made with that objective in mind. We refer to this as 'colonial astronomy'. However, other observations (including of solar eclipses and transits of Venus) were made—especially by expatriate amateur astronomers—as a result of innate curiosity or in a bid to further astronomical science. It is notable that some of the solar eclipse observations inspired the founding of Government-funded solar observatories in India, which were linked to an improved understanding of the climate and the monsoons and therefore to the economic development and prosperity of India. One way or another, astronomy was an important element of Empire in British India.

Keywords: Indian colonial astronomy; Madras Observatory; Trigonometrical Survey of India; Colaba Observatory; Calcutta Observatory; Dehra Dun Observatory; Hennessey Observatory; Kodaikanal Observatory; 1761 and 1769 transits of Venus; 1874 transit of Venus; solar eclipses of 1868, 1871, 1872 and 1898; amateur astronomers

1 INTRODUCTION

India's tryst with modern observational astronomy began soon after activity began in Europe in the seventeenth century. What commenced as individual curiosity of the European travellers to India eventually became, in the hands of powers that be, a useful tool in geographical and resource mapping of the subcontinent and scientific advancement in diverse areas.

After its invention in Europe in 1609, the story of the telescope reached Indian shores quickly enough. Father Antonio Rubino (Antonius Rubinus, 1578–1643), a Jesuit missionary in Goa, hearing of the invention, initiated efforts in 1612 to acquire one from Rome. He is understood to have first introduced the telescope in India (Baldini, 2015; Udias, 2003).

Initially, the telescope was only put to astronomical use sporadically. We come across the first published accounts of observations of the bright comets 1618 III and 1618 II by Father Venceslaus Pantaleon Kirwitzer (1588–1626), from Goa (Anonymous, 1878), where the Jesuits used a telescope to observe these two comets (Kapoor, 2016). The next incidence of use of a telescope to observe an astronomical event from Indian soil dates to 1651 (Kochhar, 1989). This was for the transit of Mercury on 24 October (3 November Gregorian calendar) from Surat by Jeremiah Shakerley (1626–1655). Coming all the way from England, he had just 80 minutes to view the transit since it was already past its greatest phase when the Sun rose.

Shakerley's 1651 observations marked the first accredited use of a telescope in India, which previously had been attributed to a French Jesuit, Father Jean Richaud, S.J. (1633–1693), who decades later began carrying out astronomical observations from Pondicherry with a 12 ft telescope (Kameswara Rao et al., 1984). Father Richaud was a member of the group of fourteen French Jesuit astronomers that went to Ayutthaya in Siam (now Thailand) in 1687 at the invitation of King Narai (1633–1688). In fact, Siam's romance with Western astronomy began in 1681 with the arrival of the Belgian Jesuit Father Antoine Thomas (1644–1709; Orchiston et al., 2021a) and continued with the arrival of a first contingent of French Jesuit astronomers in 1685. King Narai had a passion for astronomy, and the French astronomers joined him in observing a lunar eclipse on 11 December 1685 (Gislén et al., 2017; Orchiston et al., 2016). This so enthralled the King that he authorised the construction of a 'modern observatory' in Lop Buri (modelled in part on the recently completed Paris Observatory), and he also invited King Louis IV to send a second contingent of Jesuit astronomers to Siam. The aforementioned Father Richaud was a member of this second group (Orchiston et al., 2022). Although a variety of successful astronomical observations was made at Ayutthaya and Lop Buri (see Orchiston et al., 2019; 2021c; 2022), King Narai's support for Western astronomy at the expense of traditional Buddhist astrology and the emergence of a Westerner, Constantine Phaulkon, as the nation's *de facto* Prime Minister led to a coup in May 1688 (Orchiston et al., 2022). Most of the Jesuit astronomers were expelled from Siam and headed for India. Father Richaud was one of these, and he arrived in Pondicherry on 1 February 1689 (Louyat, 1982).

At Pondicherry, Father Richaud resumed astronomical activities. His telescopic discovery on 19 December 1689 that the brightest star in Centaurus, α Centauri, was a double star was an astronomically significant incident in the history of modern astronomy in India. He also observed a comet in that same month (*ibid.*). These observations were reported in the *Memoires de l'Academie Royale des Sciences de Paris*. In fact, Father Richaud is now credited as one of the independent discoverers of the sungrazing comet C/1689 X1, on 8 December (for details, see Vsekhsvyatskii, 1964: 121; also see Kapoor, 2018).

During the seventeenth century, the chief sources of information about Indian astronomy were a number of European travelogues and the communications of some of the Jesuit priests resident in different parts of India.

The eighteenth century saw sporadic but significant efforts in astronomy in India in terms of facilities, literature and observations, and in related sciences.

The most notable beginning was made when in the 1720s Mahārājā Sawāi Jai Singh II (1688–1743) of Amber built observatories at Delhi, Benaras, Jaipur, Ujjain and Mathura patterned after Ulugh Beg's at Samarkand. Mahārājā Sawāi Jai Singh II was a great scholar of mathematics and astronomy. India's introduction to the European science also happened under Mahārājā Sawāi Jai Singh II who had invited some Jesuits to Jaipur in order to get an exposure to European astronomy. He also made observations with a telescope. This telescope had been brought by Father Figueredo's astronomical mission in 1730 that was sent to Portugal earlier in 1728–1729. However, Mahārājā Jai Singh's endeavours died out with him.

The present work outlines the efforts by the British in establishing observatories in India for 'modern' astronomical observations over the three centuries prior to Indian Independence in 1947, and the succession of solar eclipses and a transit of Venus that attracted Indian and on occasions overseas expeditions. Some of these prominent astronomical events also drew the attention of expatriate amateur astronomers living in India. In this paper we discuss the emergence of the Madras, Colaba, Dehra Dun, Hennessey and Kodaikanal Observatories, and the contribution made by the Great Trigonometrical Survey of India. Some of the material presented here was drawn from Kapoor (2001; 2006) and from Kochhar and Orchiston (2017). A second follow-up paper is currently in preparation, and will be published later in *JAHH*. This will examine the emergence of observatories established by Indians, and will discuss the Royal Observatory at Lucknow, and the Trivandrum, St Xavier's College, Takhtasinghji and Nizamiah Observatories, as well as leading Indian amateur astronomers.

The places of astronomical activity in India are numerous. To retain the historical flavour, we have referred to their old names/spellings as used in the various historical accounts. For excellent reviews of the development of modern astronomy in India, see Ansari (1985), Kochhar and Narlikar (1995), Kochhar and Orchiston (2017) and Sen and Shukla (2000).

2 THE EARLY YEARS

2.1 Mapping India

Until the middle of the eighteenth century there was no detailed knowledge of the geography of India, even though many traditional maps existed and had been available. Modern contributions in this respect came from Jesuit missionaries based in various parts of India, or traveling through the country. Many of these were astronomers or geographers (Kochhar, 1991b; Phillimore, 1945(I): Chapter I; Sharma, 1982). Phillimore (1945(I): 11) describes how

> One of the earliest of the Jesuit surveyors was Father Monserrate, a member of the first Jesuit mission to the court of Akbar in 1579, which travelled "by sea from Goa to Daman, marching; thence to Surat, and on to Fatehpur Sikri … In 1581 he accompanied the Emperor on his march to Kabul,

and left a long list of geographical positions, and a most interesting little map of India."

Father Monserrate's original map, drawn ca. 1590 (Phillimore, 1945: Chapter X, Plate X), was good enough to be included two hundred years later by Thomas Call in his atlas of India, who described it as an actual survey made from Delhi to Cabul "… with a compass and corrected by observations of Latitudes from Goah to Delhi."

Starting with Delisle, Father Bouchet and Bourgignon d'Anville, the French geographers and Jesuits made a meaningful beginning in this direction. They mapped the southern peninsula better than ever before. Some of them, like Father Claude Boudier and Father Emmanuel de Figueredo came into contact with Mahārājā Sawāi Jai Singh. Based on Father Bouchet's rather crude map of southern India of 1719, Bourgignon d'Anville made a refined map of the southern region in 1737, and later, in 1752, his highly acclaimed *Carte de l'Inde*.

In 1719 Father Claude Boudier (1686–1757) came to the French mission at Chandernagore, a French Colony since 1673 in the Hooghly District of Bengal. Father Boudier was an astronomer, and he arrived with 6 feet and 17 feet telescopes, a 2-feet quadrant and some other instruments. A group of Jesuit astronomers under him commenced astronomical observations in 1730 that included solar and lunar eclipses (Udias, 2003). In 1734, he and Father Francis Pons (1698–1752) undertook the long journey to Jaipur at the invitation of Mahārājā Sawāi Jai Singh II. They left Chandernagore on 6 January 1734 accompanied by the 17-feet telescope and an astronomical clock. As they travelled, they measured the latitudes of towns along the way and used observations of the Jovian satellites to determine their longitudes. In Delhi Father Boudier recorded the solar eclipse of 3 May 1734, together with the Mahārājā's *Vedhashāla* staff. The eclipse was total over the southern fringe of Gujarat, Maharashtra, Telangana and Andhra Pradesh but partial at Delhi, at magnitude 0.7.

Joseph Tiefenthaler (1710–1785) of Tyrol was a geographer and Jesuit Missionary who was sent by his religious superiors to India to join the Jesuit astronomers at Mahārājā Sawai Jai Singh's Jaipur *Vedhashālā.* He landed in Goa in 1743 and eventually reached Surat (Sharma 1982), but the Mahārājā's passing away that same year altered his plans. He was then asked to proceed to Agra to offer his services at the Jesuit College there. Tiefenthaler laid great emphasis on determination of latitude and longitude of places in India as being fundamental to knowing its geography correctly. He travelled to many places, maintaining records of his astronomical observations and his geographical surveys. He even prepared a 15-ft long map of the Ganges (De Souza, 1994: 179–180). He had a quadrant to determine latitudes and an armillary astrolabe for longitudes. Tiefenthaler observed lunar eclipses and on 2 February 1744 an occultation of Jupiter by the Moon from Surat, and a transit of Mercury on 4 November 1743 from Goa (Phillimore, 1945: 150). By observing the occultation of Jupiter, he determined the longitude of Surat as 71° 50′ E of Greenwich and from the Sun's meridian altitude the latitude as 21° 05′ N (modern values are 21° 10′ N and 72° 50′ E). On 26 April 1744, he observed a lunar eclipse from Damaun. Tiefenthaler is said to have also recorded observations of sunspots and the zodiacal light (Herbermann, 1913a). Sen (1982) discusses Tiefenthaler's efforts at length and mentions that the Jesuit had made use of an astronomical quadrant of brass and an astrolabe (see also Mukherjee, 1985: 59). About the observatory at Jaipur, Tiefenthaler had famously commented: "qui frappe d'étonnement par la nouveauté et la grandeur des instrumens", i.e., that which strikes with astonishment by the novelty and the grandeur of the instruments.

The British, fresh from their victory in 1757 at the battle of Plassey (now Palashi), initiated scientific surveys to gain accurate geographical knowledge of the land. By 1765, the East India Company (EIC) had more or less taken over all of Bengal. In these operations lay a great strategic value that paved the way for rich dividends in the times to come. This can be gauged from the fact that the Survey of India itself was founded in 1767 in what may be termed the earliest modern scientific institution in the country. Robert Clive (1725–1774), the first British Governor of the Bengal Presidency appointed Captain James Rennell (1742–1830) the first Surveyor General, beginning 1 January 1767, with many surveyors under him. Some of them were engineer officers and others were infantry officers. They set out on a task unprecedented in India's history. In the backdrop of the ongoing wars, Rennell compiled his first *Map of Hindustan* in 1783. He had closely followed the method of D'Anville in its preparation, consulting every possible source and even ancient ones. He incorporated the valuable work by Father Tiefenthaler, carried out over a span of about thirty years, in the 1788 edition of his map (Phillimore, 1945: Chapter 1).

Astronomical observations were made from time to time by the Jesuit missionaries and the English surveyors to determine the latitudes and longitudes of places by observing the meridian altitudes of celestial objects, eclipses of the Jovian satellites, and—as we shall see below—even transits of Venus (Ansari, 2000; Phillimore, 1945; 1954; 1955; 1958).

2.2 The 1761 and 1769 Transits of Venus

The first modern astronomical observations that hold a significant place in the history of Indian astronomy were those of the transits of Venus in 1761 and 1769, made from several places in India (Kapoor, 2013; 2014). These transits provided an excellent opportunity to measure the solar parallax, and they also could be used to determine longitude.

There are about 12 transits of Venus in a millennium. These have a 243-year repetition, with two transits in December, eight years apart, followed 121.5 years later by two transits in June, eight years apart. There have been seven transits of Venus since the invention of the telescope. The most recent transits were on 8 June 2004 and 5–6 June 2012, both of which were visible from India.

After the advent of the telescope, the first transit of Venus predicted by Johannes Kepler (1571–1630) occurred on 7 December 1631 CE. The French astronomer Pierre Gassendi (1592–1655), tried to observe it from Paris but did not succeed since the transit was already over when the Sun rose in Paris. As is now well known, the British astronomer Jeremiah Horrocks (1618–1641) deduced that there would be another transit, on 4 December 1639, which he and his friend William Crabtree (1610–1644) observed from Liverpool and Salford respectively. Horrocks concluded that the solar parallax was 14″, smaller than the figure of 57″ that Kepler had proposed. This new parallax value corresponded to a mean Earth–Sun distance of 15,000 Earth radii, and since this was substantially different from the prevailing value, it had attendant implications for the canonical worldview (Sheehan and Westfall, 2004)

It was James Gregory (1638–1675) in 1663, and later Edmund Halley (1656–1742) in 1691, who proposed that one should be able to determine the solar parallax and deduce a precise value for the distance to the Sun by timing the ingress and egress of Venus on the disk of the Sun from different locations on the Earth (*ibid.*). Halley never got to test this proposition as he died in 1742 CE, and the next transits were in 1761 and 1769. These transits evoked great scientific interest in Europe. As a result, they were observed from many locations in Europe, and in addition many expeditions were mounted to diverse places around the globe. What then followed is history, and has been well documented, e.g., see van Gent (2004) and Woolf (1959).

2.2.1 Transit Observations Made From India

It was within this atmosphere of emerging scientific endeavour that the 1761 transit of Venus occurred. According to Love (1995: 590), the Royal Society of London prepared to send two astronomers to Fort Marlborough to carry out observations of this transit, and the EIC decided to provide local support to them. The EIC Directors also called for volunteers to contribute observations of the transit, and also instructed 'any competent persons' in Fort St. George at the time also to conduct observations.

At Madras, the transit of 6 June 1761 was observed from the top of the Governor's house, Fort St George by an astronomer, the Reverend William Hirst (1761–1762) with a "… reflecter 2 feet long, made by Mr. Adams, of Fleetstreet, London." Hirst made a significant observation—of having seen at the moments of ingress a nebulosity about the planet. That constituted the discovery of the atmosphere of Venus, duly recorded in his communication as presented in Volume 52 of the *Philosophical Transactions of the Royal Society* of London. The discovery of the atmosphere of Venus has been attributed to Mikhail Lomonosov alone that he made during the same transit observed from the St. Petersburg Observatory (Pasachoff and Sheehan, 2012; Shiltsev, 2014). The other observers of the transit in India were William Magee (1763), a notary public in Calcutta, and Bartholomew Plaisted. Plaisted originally was trained in nautical astronomy as a sailor, and developed an aptitude for determining latitudes as he surveyed the Chittagong coast in 1760–1761, mostly using observations of the Sun (Phillimore, 1945: 153). He observed the transit of Venus from Chittagong (now in Bangladesh), and the Astronomer Royal used these observations to derive a longitude of 91º 45′ E for Islamabad, as that area was known since the Mughal occupation (*ibid.*). Chittagong, along with Burdwan and Midnapore had only been ceded to the EIC in the previous year. The transit was also observed by some Jesuit priests from Tranquebar (Tharangambadi) in Tamil Nadu and from Pondicherry (see Kapoor 2013).

The next transit would happen on 3–4 June 1769. In 1768, the Royal Society petitioned King George III to organize scientific expeditions to observe the forthcoming transit of Venus. Observations were planned to be car-

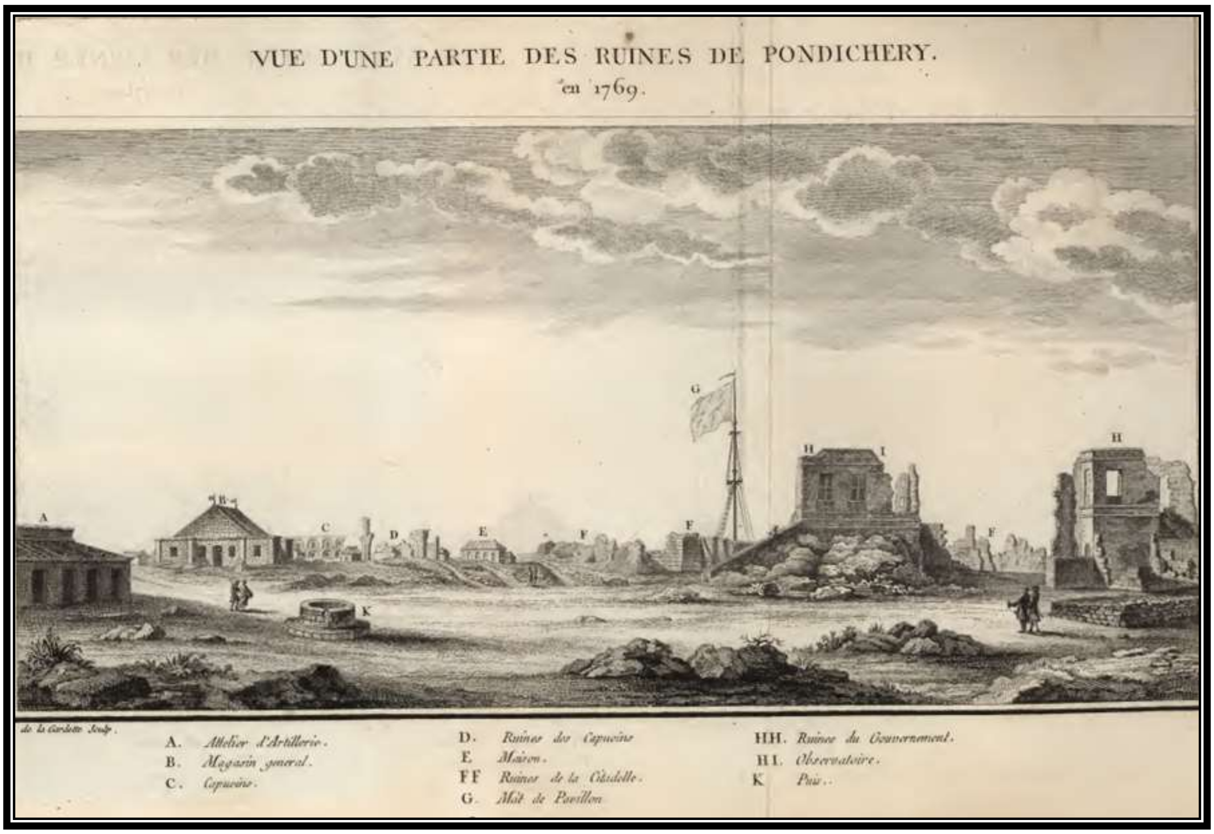

Figure 1: The ruins of Pondicherry in 1769 seen from the north. Le Gentil set up his observatory in the ruins of the former Governor's palace, in the structure to the right of the flag pole (image adopted from Le Gentil, 1779).

ried out from places far apart and the astronomers were prepared to travel long distances. The most famous expedition was undertaken by James Cook (1728–1779) to Tahiti who was specially promoted to the position of Lieutenant and given command of the HM Bark *Endeavour* as well as serving as one of the two official astronomers. The other was Charles Green (1734–1771). As outlined in Orchiston (2017), successful observations were carried out from three different Tahitian locations by the two astronomers, one of the supernumeraries, and by officers and seamen especially trained for the task, but controversy surrounds their published results.

In India, the transit was observed from Dinapoor (25º 27′ N) by Captain Luis Degloss, of the Engineers (Degloss 1770), and from "… Phesabad, lat. 25º 30′ north …" by Captain Alexander Rose of the 52d Regiment (Rose 1770). Captain Degloss had made his observations with three quadrants and a reflecting telescope. At sunrise it was cloudy but at 5h 20m 32s, "… the Sun disengaged from the clouds when Venus appeared on the ☉'s disk …"; he timed the beginning of the egress at 7h 5m 22s and end of the egress at 7h 23m 36s.

Captain Rose observed the transit with a telescope and a stop-watch when it was already in an advanced stage. He only saw the egress and timed the first (at 6h 52m 25s) and the last contacts (7h 10m 47s) (i.e. contacts III and IV, respectively), their interval being 18m 22s.

Among the most dedicated to observe an astronomical phenomenon from lands afar, the French astronomer Guillaume Le Gentil (1725–1792) deserves the most honourable mention. After he failed to reach India in time to observe the 1761 transit, Le Gentil waited for the next one on 4 June 1769, spending the intervening years in frustrating journeys and sojourns. He returned to Pondicherry in March 1768 and set up his observatory in the ruins of the former Governor's palace (Figure 1). Le Gentil was duly equipped to observe the forthcoming transit of Venus but was, to his misfortune, clouded out. Further details about him are given in Hogg (1951) and Kapoor (2013).

The transit of 1761 produced solar parallax values that ranged from 8″.28 to 10″.6. In the observations of the transit of 1769, the value improved but ranged from 8″.43 to 8″.80. The divergence in results implied large differences in the value of the distance to the Sun. That did not satisfy the astronomical world (Orchiston, 2005). There was thus no way but to wait for the next transit pair, that would happen in 1874 and 1882. By this time, the techniques for angular measurements and geo-positions and the astronomical instrumentation had greatly improved. The astronomers could now indulge in photography and spectroscopy. In the meantime, the Solar System itself had grown bigger with the discovery of Uranus by Sir William Herschel on 13 March 1781 and of Neptune on 23 September 1846 by Johann Galle and Heinrich d'Arrest.

The transits of Venus of 1874 and in 1882 gave rise to worldwide excitement and scientific activity. In India, the transit of 9 December 1874 was well observed and from many different places (Kapoor, 2014). Details follow later in this paper. As for the transit of 6 December 1882, the Sun had already set over India when the transit began.

3 MODERN OBSERVATORIES IN BRITISH INDIA

3.1 The Beginning

Through the late eighteenth and early nineteenth centuries, the Indian Subcontinent saw major changes on the political and social fronts. On the political front, the EIC brought a major part of India under its control. This they divided into four administrative regions, in the form of the Presidencies of Bengal, Bombay, Madras and the North-West.

The determination of longitudes was of great importance, especially for navigation. Measurement of latitude was rather easy using meridian observations of the Sun or a star. In contrast, accurate longitude determination was far more difficult. One had to wait for a suitable celestial phenomenon (e.g. a solar or lunar eclipse, or a Jovian satellite event) that would enable the accurate measurement of time difference between a reference meridian and the observing site. This only became possible with precision when portable marine timekeepers, invented by John Harrison (1693–1776; National Maritime Museum http://www.nmm.ac.uk/harrison; accessed 14 April 2011) became widely available in the first half of the nineteenth century. These gradually replaced the older 'lunars' method for longitude determination (see de Grijs, 2020). Just how profound the quest was for the accurate determination of longitude is reflected in the following quote from Phillimore 1945: 151):

> British Government had long offered a reward for some sure means of effecting it [202]. An Act of Parliament was passed as late as June 1714, offering rewards for either "a Time keeper, the Principles whereof have not hitherto been made public", or for "improved Solar and Lunar Tables"; the reward to be £5,000, if such method determines the said Longitude to one Degree of a Great Circle, or Sixty Geographical Miles ... £7,500, if it determines the same to Two Thirds of that Distance; and ... £10,000, if it determine the same to one half of the said distance", and provision was made for satisfactory tests by the "Commissioners for the discovery of the Longitude at Sea[5] [154]. (See Phillimore, 1945 for the numbered references.)

With the expansion of its political hold, the EIC undertook geographical mapping of India with a view to expand their territories. It was imperative to impart astronomical knowledge to the surveyors who had been employed by the Government. The Reverend William Smith (d. 1787) who came to Calcutta as a private tutor was greatly interested in astronomy. Although he was not in the employ of the EIC, he devised a short but accurate method of determining longitude at sea, by measuring a single altitude of the Moon. Thanks to his observational skills in July 1775 he was inducted into Colonel Upton's political mission to Poona to survey the country and use astronomical observations to determine the geographical coordinates of places visited. The observations were made with a 3½ feet Dollond telescope. Reverend Smith returned to England in 1778 (Phillimore, 1945: 384–385).

Thomas Deane Pearse (1741–1789) was another astronomer in Calcutta, and he maintained a private observatory at his quarters at the Treasury Gate of Fort William. He made regular observations and deduced the precise position of Fort William: 22° 33′ 10″.55 N and 88° 22′ 07″ E. In the southern region, Pearse carried out astronomical observations to determine latitude and longitude in the course of his marches to and from Madras during the Mysore War of 1781–1784 (Phillimore, 1945: 154).

Reuben Burrow (1747–1792) who came to Calcutta in 1783 was a mathematician, astronomer and orientalist. He had been assistant to Sir Nevil Maskelyne, the Astronomer Royal. Soon after his arrival, he wrote to Warren Hastings (1732–1818), the first Governor General of Bengal from 1772 to 1785, of the importance of research into the Hindu astronomy works and a study of the Indian astronomical observatory at Benaras. He offered to study these and also make such astronomical observations as would provide a sound basis for the survey of India. In Calcutta, he was soon appointed as a mathematics teacher for the engineer officers at Fort William. For his Indian studies, he taught himself Sanskrit and collected many Sanskrit and Persian manuscripts. He became a founding member of the Asiatic Society and contributed many papers to its Journal. One of these papers was titled: "A proof that the Hindoos had the binomial theorem" (Burrow, 1799).

In 1787, the Government appointed Burrow to ascertain the latitudes and longitudes of different places in India through precise astronomical observations. With the funds approved, he collected in Calcutta a 15-inch brass sextant, an astronomical quadrant, a Dollond achromatic telescope, an Arnold chronometer, as well as a thermometer and a marine barometer, which he then used on various expeditions. In 1789, he published his observations in *Asiatic Researches*, and in the personal journal that he maintained he mentioned his regret that

> There is no Observatory nor Astronomers in India to make corresponding observations. This deficiency would have been remedied had Mr. Hastings stayed a little longer in India, for on representing the advantage of such an institution to him, he approved of it immediately. (Phillimore, 1945: 162).

However, as Phillimore (1945: 163) commented, "The Directors showed no sympathy for Burrow's wish for an observatory."

Regular astronomical observations were begun at Calcutta when in 1794 Colonel Robert H. Colebrooke became the Surveyor General. He made a series of observations, including of the 29 May 1798 lunar eclipse from Chouringhy in Calcutta, timing of immersion and emersion of several prominent maria and craters, and he compared his eclipse timings with those made at Greenwich. He found totality lasted 49m 47s at Calcutta, compared with a duration of 50m at Greenwich (Colebrooke, 1826: 285–286). Then, while reporting observations of the eclipses of the Jovian satellites between 1797–1803 made with a telescope of 2.7-inch aperture, 43-inch focus and power of 80X, he mentioned these made from "Mr. Bristow's house at Chouringhy, about 3^s of longitude in time, east of Fort William, the longitude of which was settled by Colonel Pearse at 5h53m28s.5." (Colebrooke, 1826: 286–287).

Western India too felt the need for an astronomical observatory. That sentiment was expressed, for instance, when a Great Comet showed up in the sky in September 1807. It had been observed from some places in India and the reports also appeared in the print (see Kapoor, 2019). For instance, Sandeman (1868: 181–182) described the apparition thus:

> THURSDAY October 8, 1807
> In our Extra Gazette of the 3rd instant, we had the honor to announce to our readers the appearance of a Comet, and our determination to submit, to their perusal, such information regarding the place and course of the phenomenon, as we might be able to obtain from men of science, The Comet was undoubtedly seen on the 21st of September, and, we have reason to believe, at an earlier date, but though seen, it seems to have excited very little of the curiosity of those who beheld it, and was not generally observed before the 2nd of October, when the appearance of the star was so luminous as to attract the almost universal notice of the Settlement … If any arguments were wanting to convince our Countrymen of the propriety of establishing a public observatory at this place, we think that the appearance of this Comet, and the unprepared state in which our men of science have (necessarily) been found on the occasion, would be sufficient to bring home conviction to the minds of our most skeptical readers … At Bombay, a public observatory has, we believe, been already projected by the Literary Society of that place. At Madras (fortunately for the interests of science) a public observatory already exists; and we shall be sorry to find our own is the only presidency in India, which can be reproached with the absence of an establishment at once …

Note that the aforementioned Bombay Literary Society was founded in November 1804 along the lines of the Asiatic Society of Bengal (founded in 1784) to promote scientific discussions. In 1805 it started a library, a museum and an astronomical observatory (Sangwan, 2000: 19).

Towards the end of the eighteenth century the first modern astronomical observatory in India was established in Madras. However, it was a private one, established in 1786 by William Petrie (1747–1816; Figure 2), an officer with the EIC. This marked the beginning of modern observational astronomy in India. In Bombay, the EIC established a facility for astronomical observations and time-keeping much later, at Colaba, in 1823. The Company also established an observatory at Calcutta in

Figure 2: A portrait of William Petrie (http://www.indianetzone.com/63/william_petrie.htm).

1825 in the Surveyor General's Office in Chowringhee. This was championed by the Surveyor General of India V. Blacker (1778–1826). Its job was to serve the Survey Department. That apart, a few other observatories were erected in the nineteenth century in different parts of the country under the Royal personages and individuals interested in astronomy, and these will be discussed in a later paper.

The British dominance had begun to greatly overwhelm India's political, cultural and economic life. The period saw the advent of an Indian Renaissance that placed Medieval India on the path to modernity. Soon there was a need felt for good schools to teach English. The General Committee of Public Instruction was formed in 1823 at Calcutta as a part of the policy of England on education in India, in order to

> … equip itself with facts about the state of education in the territories under Bengal Presidency and to suggest ways and means for the better instruction of the people. (Majumdar, 2007: 42).

The quest for English education spread from Bengal into the neighbouring regions, as it did in the other Presidencies and Provinces, resistance from early British rulers notwithstanding.

The Renaissance brought science to the interested in Indian languages through the efforts of several prominent figures (Ansari, 2002). On the popular front, a number of reports about 'irregular celestial phenomena' (eclipses, comets, meteors, meteorites, meteor showers, as well as earthquakes) were published in newspapers, magazines and scholarly journals. These accounts came largely from British engineers and educationists, and included insightful information about the events, which shed light on their likely nature.

Figure 3: Michael Topping (courtesy: Indian Institute of Astrophysics Archives; henceforth IIAA).

3.2 Madras Observatory

In 1785, Marine Surveyor Michael Topping (1747–1796; Figure 3) made longitude observations in the Maldives and in Ceylon on his voyage to India. He continued doing so during his overland journey from Masulipatam along the coast to Calcutta. In a report he indicated that if correspondent observations were made at Madras it would have been useful. The Board was impressed by his work and ordered him to continue south of Madras and take steps so that corresponding observations could be made at Madras. Here, William Petrie, a member of the Madras Council and an amateur astronomer, came forward to provide the needed assistance for him to achieve accurate deductions and even offered continuity of the operations at the Presidency.

Petrie had set up a private observatory in 1786, and when he was planning to go on leave early in 1789 he offered to gift this to the Government. Topping saw in this a great opportunity:

> The Astronomical observatory built by William Petrie Esq. for his own private use, but which by his permission ... has, since the commencement of my operations, been occupied in the public service, becomes liable ... to be

> transferred into other hands, and ... is in danger of being no longer accessible … Mr. Petrie ... very liberally assursured me that the building ... was at my entire disposal for the public service and that I was at liberty to remove it … Astronomy has ever been acknowledged as the Parent and Nurse of Navigation … and it is doubtless … that the Hon'ble Court have come to the resolution of thus affording their support to a science, to which they are indebted for the sovereignty of a rich and extensive empire. (Phillimore, 1945: 171–172).

The Board asked Topping if there was a suitable place for the new observatory and forwarded his proposition to the Directors. The following year, the Directors agreed that "… the establishment of an Observatory at Madras would be of very great advantage to Science." (Phillimore, 1945: 172).

Petrie's intention, expressed years later in a memorandum of 4 September 1804 to the Governor of Madras, was "… to provide navigational assistance to the company ships, and help determine the longitudes and latitudes of the company territories." (Madras MS Records: 76). Petrie possessed three 2¾-inch achromatic telescopes of 3½ feet focal length by John Dollond; an astronomical clock with compound pendulum by John Shelton (similar to the one used by James Cook during the 1769 transit of Venus);[1] a quadrant by John Bird; and a 20-inch transit instrument by Stancliffe (Kochhar, 1985a; 1985b). The longitudes were determined from observations of Jovian satellite phenomena. The first observation on record, on page 164 in the MS Records at the IIAA, dates to 5 December 1786 and pertains to the determination of the co-ordinates of Masulipatam Fort Flagstaff.

In 1792 the observatory was moved to a new site at Nungambakkam, in Madras, and a new building was designed by the Company's new Astronomer, Michael Topping. This new facility was renamed Madras Observatory, and is shown in Figure 4. Note the small drum-shaped dome for one of the Dollond refractors and the two transit slits that extended from one wall across the roof and down the other wall; one of these would have been used by the Stancliffe transit telescope. As Phillimore (1945: 174) later observed,

> Madras Observatory was a worthy monument to Michael Topping, and continued to be the home of important scientific work directed by a succession of distinguished astronomers, until in the year 1899 its operations were transferred to Kodaikanal, a change which amongst other advantages affords a clearer atmosphere.

In 1810, its ownership changed yet again when it became an official Colonial Government observatory, under the control of the Surveyor General of Madras (Kochhar, 1991b). Madras Observatory therefore has a long history (see Ananthasubramanian, 1991), but this was "... a chequered history for more than one hundred years …" (Kochhar, 1985b: 288). The noted geographer Sir Clements Markham (1878: 340) later had this to say about the Observatory in *A Memoir on the Indian Surveys*:

> The Madras Observatory is now the sole permanent point for astronomical work in India, and the only successor of the famous establishments founded by Jai Sing. It has been presided over by a succession of six able and accomplished astronomers, it has produced results which entitle it to take rank with the observatories of Europe, and its present Director is engaged in the prosecution of labours which are of great importance to astronomical science.

The Director referred to above was Norman R. Pogson, who served in that capacity from 1861 until 1891. More about him later.

As we have seen, in 1789 the Observatory passed from Petrie's private ownership to the EIC and Michael Topping's Directorship. Topping also 'inherited' John Goldingham (1767–1849; Kochhar, 1985b), who initially was Petrie's assistant. Prior to his Madras Observatory appointment, Topping had already undertaken a much-needed survey of the maritime-unfriendly Coromandal coast, and during 1786–1787 he determined the latitude and longitude of a number of different locations. In 1794 and 1795, Goldingham and Topping determined the longitude of Masulipatam, using observations of Jovian satellite eclipses (Taylor, 1832). Madras Observatory then became the reference meridian for the trigonometrical survey of southern India which was initiated by the EIC. A precise determination of the longitude of the Madras Observatory was thus essential, so that longitudes required during the survey could be measured. William Lambton began the survey at Madras on 10 April 1802, where a baseline measurement relating to the longitude of Madras was made. From 1818 this ambitious project was known as the

Figure 4: The hand-drawn image of Madras Observatory at Nungambakkam, on the banks of the Cooum River (taken from the manuscript "Astronomical Observations Madras 1792"; courtesy: IIAA).

Great Trigonometrical Survey of India, and the intention was to cover the entire Indian subcontinent (Kochhar, 1991a).

In 1793 Toppings' assistant John Goldingham also began making systematic meteorological measurements at the Observatory. He maintained a meteorological register for barometric pressure, which was measured at sunrise, 10 am, 12 noon, 2 pm, sunset and 9 pm from 1796 until 1825, but with a gap through 1808–1812 during his years of absence (Alvi, 1976).

Following Topping's untimely death in 1796, Goldingham served as Director for two discrete intervals, 1796–1805 and 1812–1830. During the intervening period, while he was away in England, Captain John Warren (1769–1830) took charge.

We have seen above how in 1802 Madras Observatory came to serve as the reference meridian for the Trigonometrical Survey of India (Markham, 1878). Subsequently, in 1807, Warren redefined the longitude as 80° 17′ 21″ E, and this remained the accepted value for almost a century, until 1905 (Phillimore, 1950 (II): 195). Warren also was concerned about the value of the latitude for Madras, and he made observations of zenith distances of selected stars from October 1806 to June 1807 with a zenith sector loaned to the Observatory by William Lambton (*ibid.*). As a result, he revised the latitude by several arcseconds.

Goldingham was eventually succeeded by Thomas Glanville Taylor (1804–1848) in 1830. He, too, maintained the meteorological observations, and the tradition was duly followed by successive astronomers, and a series of entries for thermometer readings, the rain gauge, wind and weather was published over the years. It was under Taylor's direction that high altitude meteorological observations were carried out at a bungalow built for the purpose atop Dodabetta at a height of 8640 feet (2633 m) in the Nilgiri hills in Tamil Nadu. Observations began in February 1847, with an Osler anemometer, a barometer, thermometers and rain gauges. The measurements were taken at 9:40 am and 3:40 pm, the supposed hours of maxima and minima, and continued until 1858 (Markham, 1878: 280–281). More recently, this robust suite of historic Madras Observatory meteorological records has been used by climatologists to measure fluctuations in the El Niño southern oscillation phenomenon across the Indian Ocean basin and the Indian summer monsoon (Allan et al., 2002).

In 1804 Madras Observatory received a 12-in Troughton circular alt-azimuth instrument and a portable transit by Jesse Ramsden (1735–1800; Chapman, 1996; McConnell, 2007). Warren resigned in December 1811 and Goldingham resumed his duties on 17 February

1812. In 1830, the Observatory acquired a 5-foot transit instrument, a 4-foot mural circle and a 5-foot equatorial telescope, all by Dollond. Once in office, Taylor lost no time installing these instruments (Kochhar, 1985b), and he provided information about this in the Observatory's publications (Taylor, 1832: Preface). For example, he wrote the following about the transit telescope:

> The five feet Achromatic is exceptionally well and steadily mounted on a mahogany frame armed with brass, and being supplied with two graduated circles and a long axis moving on a graduated arc, it has occasionally been employed as an equatorial in making rough observations out of the meridian in addition to its other uses in observing Occultations and Eclipses. (*ibid.*).

The introduction of these new instruments enabled work of greater astronomical relevance and precision to be carried out at the Observatory.

Phillimore (1954: 196) lists the only available instruments maintained around this time: the transit telescope by Stancliffe, a portable transit by Ramsden, three astronomical clocks, three Dollond telescopes and a circular instrument (we presume this was the meridian circle that Sen (1989) refers to). Warren spoke very highly of this last-mentioned instrument.

As was the norm for British colonial observatories at this time, research at Madras Observatory focused on positional astronomy, and the transit telescope was used to accurately determine the positions of bright stars. The culmination of these early efforts was the preparation by Taylor of the famous catalogue of 11,015 stars in the southern sky, epoch 1 January 1835, titled *A General Catalogue of the Principal Fixed Stars from Observations Made at The Honourable The East India Company's Observatory at Madras in the Years 1830-1843* (Taylor, 1844). See Figure 5. Taylor's catalogue was supplemented by further observations made between 1849 and 1853 of 1440 stars selected from the British Association Catalogue, and these were reduced to epoch 1 January 1850 by his successor W.S. Jacob (1813–1862) and published in 1854 (Worster and Jacob, 1854). The 'Madras Catalogue', as it came to be known, was acclaimed by the Astronomer Royal, George Airy (1801–1892) in his 1854 address to the Royal Astronomical Society:

> I must characterise the Madras Catalogue of our late member, T.G. Taylor, as the greatest catalogue of modern times. In the number of observations and the number and distribution of stars, and the circumstance that the observations were made, reduced, combined, and printed, at the same place and under the same superintendence, it bears the palm from all others. But this was the fruit of an endowed observatory, the work of an astronomer and competent assistants, whose strength was not exhausted by any other employment. After this come such works as Groombridge's Catalogue ... (Airy, 1854: 145).

Taylor's zeal in this pursuit is reflected in the following comments that he included in the *Results of Astronomical Observations Vol. IV*:

> At the outset of my Astronomical career at Madras, it occurred to me that one of the most useful purposes to which I could devote the Madras Instruments was that of determining the places of a large catalogue of Stars limiting the number of observations to an extent that might leave me sure to two or three tenths of a second of time for the Right Ascension, and, to two seconds of space for the Declination ... (Taylor, 1838: 85).

The Madras Catalogue was subsequently revised by the *Nautical Almanac* in 1893 (see Kochhar, 1991b).

However, these stellar positional measurements were not the only astronomical observations conducted at Madras Observatory. Solar System objects and events, and occultations of stars and planets by the Moon were also of interest. Goldingham's observational work was predominantly devoted to eclipses of the Jovian satellites, and these were published in five volumes of the Observatory's publications, namely, *Astronomical Observations*, *Madras 1825–1827* … (4 volumes) and *Madras Observatory Papers* (1827). These volumes also included observations of eclipses of the Sun (on 1 February 1813, 16 July 1814, 15 May 1817 and 3 March 1825) and of the Moon (on 22 August 1812). Goldingham (1827) also communicated a paper to the Royal Astronomical Society in London on the longitude of Madras determined based on observations of eclipses of Jupiter's first and second satellites made between 1817 and 1826.

While at Madras Observatory, Taylor was an independent discoverer of the Great Comet of 1831 (C/1831 A1). He discovered this on the same day as John Herapath (1831), but

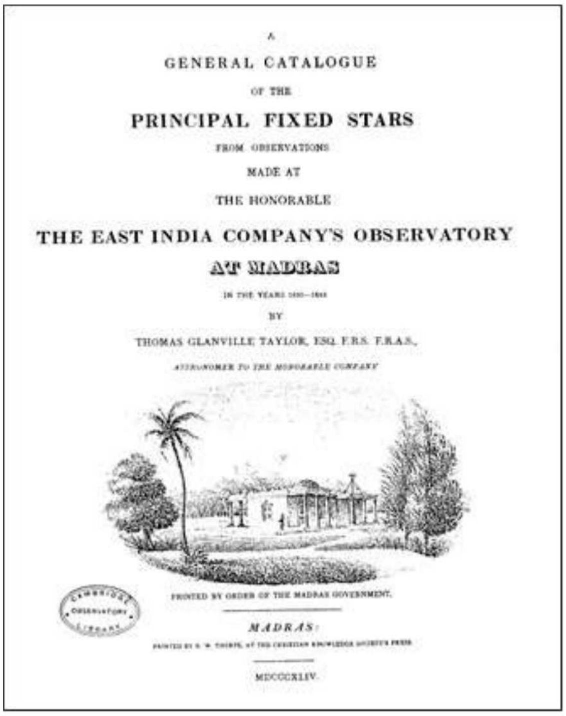
A
GENERAL CATALOGUE
OF THE
PRINCIPAL FIXED STARS
FROM OBSERVATIONS
MADE AT
THE HONORABLE
THE EAST INDIA COMPANY'S OBSERVATORY
AT MADRAS
BY
THOMAS GLANVILLE TAYLOR, ESQ. F.R.S. F.R.A.S.,
ASTRONOMER TO THE HONORABLE COMPANY
PRINTED BY ORDER OF THE MADRAS GOVERNMENT.
MADRAS:
MDCCCXLIV.

Figure 5: The cover of T.G. Taylor's *A General Catalogue of the Fixed Stars From Observations Made … at Madras* (courtesy: ADS).

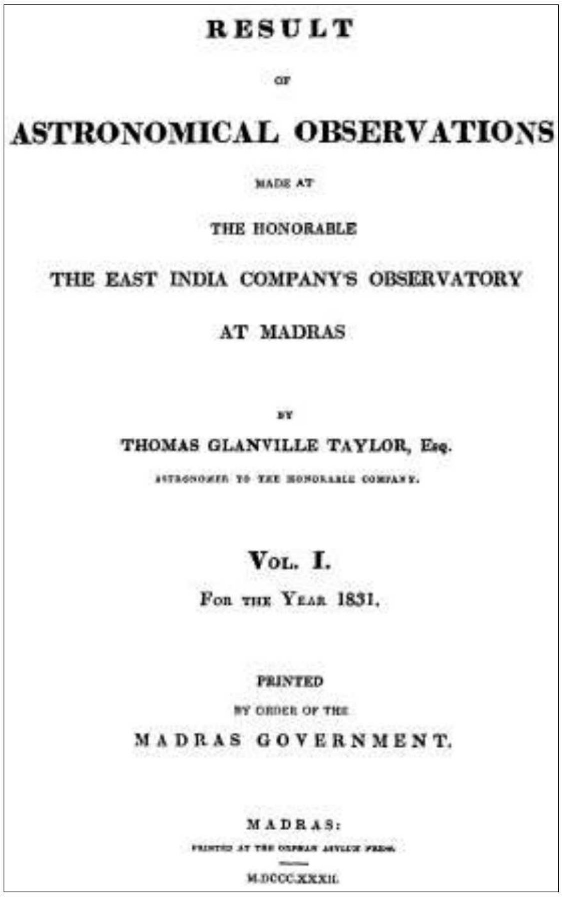
RESULT
OF
ASTRONOMICAL OBSERVATIONS
MADE AT
THE HONORABLE
THE EAST INDIA COMPANY'S OBSERVATORY
AT MADRAS
BY
THOMAS GLANVILLE TAYLOR, Esq.
ASTRONOMER TO THE HONORABLE COMPANY.
VOL. I.
FOR THE YEAR 1831.
PRINTED
BY ORDER OF THE
MADRAS GOVERNMENT.
MADRAS:
PRINTED AT THE ORPHAN ASYLUM PRESS.
M.DCCC.XXXII.

Figure 6: The cover of the 1832 Madras Observatory publication listing Taylor's various observations of Comet C/1831 A1 (Great Comet) (courtesy: ADS).

several hours earlier (in fact on 7.00972 January 1831 UT), and he continued to observe it until 20 February (Kapoor, 2011). The Observatory subsequently published these observations (Taylor, 1832). Figure 6 shows the title page of the Observatory's publication where observations of the comet are reported. Taylor also observed a transit of Mercury on 5 May 1832 with the Dollond five feet achromat. The ingress was missed, but he did time the passage of the centre of the planet's disc and the egress. High winds shook the telescope and prevented further observations (Taylor, 1835: 113).

Quite apart from its astronomical research, Madras Observatory also provided a local time service (see Kochhar, 1991a). Since the local time (based on the transit of stars or the Sun) depended on the longitude of a place, for time-keeping purposes a standard longitude was chosen for a region, a state or a country. In 1802 Goldingham fixed the latitude and longitude of Madras Observatory at 13° 05′ 24″ N and 80° 18′ 30″ E, respectively, from eclipses of Jovian satellites and culminations of the Moon (although that was not the final word, since further longitude determinations were made subsequently). That started the first use of the current time zone, with the day beginning at midnight. The clock at the Observatory was linked to a gun at Fort St. George that was fired at 8 pm every evening for the purposes of time-keeping and to serve as the standard time (cf. Kinns, 2020). A similar service was provided for ships in Bombay Harbour by Colaba Observatory (*ibid.*), which was founded in 1823 by the EIC (see Alvi, 1976). For civil purposes, a standard time was assigned for India much later by rounding off to 5 hours 30 minutes ahead of Greenwich Mean Time. Pogson (1867) noted in his report on the Observatory's activities for the year 1 May 1865–30 April 1866 that

> The Madras mean time of the flash of the 8 p.m. gun has been carefully noted, and published as formerly, to facilitate the rating of chronometers in the Roads. It is intended as early as possible to carry out the long contemplated telegraphic discharge of the Fort and Mount guns, and the erection of three sympathetic electrical clocks, for the convenience of the public in various parts of Madras.

After Charles Michie Smith shifted the astronomical activities from Madras to Kodaikanal in 1899, Madras Observatory focused on meteorological work, and the only astronomical work that continued there—up until 1931—was conducted in order to provide the time service. Today, Indian Standard Time (IST) is taken to be UT + 5.5 hrs, which is solar time at a longitude of 82.5° E, a location that is a little west of Mirzapur, near Allahabad.

Of the other non-astronomical work, mention must be made of the Observatory's participation in the Göttinger Magnetischer Verein (Göttingen Magnetic Union), the world-wide network of 53 magnetic observatories (including 18 non-European ones) initiated by Alexander von Humboldt, Carl Gauss and Wilhem Weber to record variations in the intensity and direction of the Earth's magnetic field. Simultaneous readings were taken off the magnetometers every five minutes on specific days during 1836–1841. In addition to Madras Observatory, other Indian observatories that participated in this international collaboration were located at Shimla and Trivandrum (now Thiruvananthapuram).

The results of this international geomagnetic project were collated and subsequently published by Gauss and Weber (see Gubbins and Herrero-Bervera, 2007: 729–733). Taylor even published his observations in *The Journal of The Asiatic Society of Bengal*, where he wrote:

> Notwithstanding the value which has of late years been attached to observations of the Magnetic dip and Intensity, I may, I believe, safely state, that the whole of British India has failed to put on record a single good act of experiments to this end … (Taylor, 1837: 374).

From his observations made on 26 April 1837 he provided a value of the Dip as 6° 52′ 30″ N. He further noted that

> During the present century, I cannot find that any observations for Dip have been made at Madras, but there is one result on record dated 1775, when Abercrombie found it to be 5° 15′ N; if this result can be trusted, it would appear that the Dip is on the increase at the rate of 1′ 34″ in a year. (Taylor, 1837: 375).

This was the first publication on geomagnetism from India. Jointly with John Caldecott (1800–1849), Taylor also carried out geomagnetic observations at several other places in the region, but these were never published (see Sthanapati, 2010). Caldecott was an amateur astronomer who became the Director of Trivanthrum Observatory, which will be discussed in the follow-up paper to this one. Magnetic observations at Madras were also continued in later years (e.g., see Pogson, 1884 for further details).

Taylor's Directorship ended in 1848, and it is only fair to say that Madras Observatory built on his solid foundation and flourished under subsequent Directors. Taylor's successor was W.S. Jacob (1813–1862) who, before moving to Madras Observatory had a small private observatory of his own in Poona (now Pune), which he had set up in 1842 with a 5-feet Dollond equatorial (Jacob, 1843). Between 1845 and 1848 he carried out astronomical observations. He observed the rings of Saturn, and used eclipses of the Jovian satellites to determine the longitude of Poona. However, his main interest was in cataloguing binary stars and investigating their orbits. Thus, while he was at Madras Observatory (from 1848 to 1858) he added double stars to the research repertoire. Jacob (1854; 1857) followed Taylor's lead and published papers in *the Monthly Notices of the Royal Astronomical Society*, thus bringing the Observatory's work to a wide international audience.

In 1850 the Observatory was housed in a commodious new building, complete with two domes for telescopes (Phillimore 1945: 174). Figure 7 shows the appearance of this building in 1880.

Norman Pogson (1829–1891; Dreyer, 1892; see Figure 8) began his career as an astronomer at George Bishop's South Villa Observatory in London, where he trained under J.R. Hind (1823–1895), and he then worked at the Radcliffe Observatory and at Hartwell House Observatory. When he commenced as Director at Madras Observatory in February 1861 Pogson was already well known as the founder of the modern logarithmic magnitude scale (Jones, 1967), and he immediately commenced a series of astronomical observations with a new 8-inch Cooke equatorial, including the solar eclipse of 7 July 1861, the Great Comet of 1861 (C/1861 J1 Tebbutt) and the 11 November 1861 transit of Mercury (see Pogson, 1861). During his Madras directorship, he also discovered five new asteroids and five variable stars (Kapoor, 2010; Reddy et al., 2007). In addition, in 1867 Pogson's Indian Assistant C. Ragoonatha Charry (1828–1880; Figure 9; Venkateswaran, 2021), discovered that R Reticuli was a variable star (see Kameswara Rao et al., 2009).

Meanwhile, Pogson's pioneering observations made during the 18 August 1868 total solar eclipse will be discussed latter, in Section 4.1.

Figure 7: Madras Observatory as it appeared between 1860 and 1890 (courtesy: IIAA).

When the first author of this paper made a field visit to the grounds of the Regional Meteorological Centre at Nungambakkam, Chennai, in July 2011 he found there were a few remaining relics of the old 1792 Madras Observatory building. Figure 10 shows what is referred to as the '1792 Monument' in the India Meteorological Department document of 1976 (see Alvi, 1976), which was preserved in its present form in 1948. This was the longitude datum point for Lambton's trigonometrical survey. This 10 tonne, 18-foot high granite pillar was in the centre of the 1792 Observatory building shown in Figure 4. At its base it measures 4 feet in diameter, and it is 2 feet at the top. It was erected by Sir Charles Oakley, the then Governor of Madras. Its top carries the name of Michael Topping, who had designed the Observatory. Originally the Troughton 12-inch Altitude and Azimuth instrument was mounted on top of the pillar, which was designed to be vibration-free.

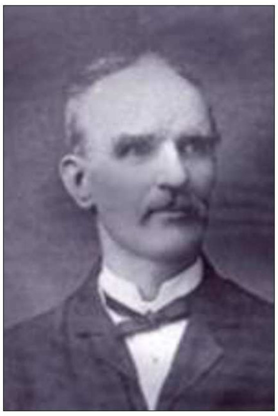

Figure 8 (left): Norman Pogson (courtesy: IIAA).

Figure 9 (right): C. Ragoonatha Charry (courtesy: IIAA).

Also present at this site is a granite slab that originally was fixed to the 1792 Observatory building (Figure 11). This carries a Latin inscription, which translates as:

> For Astronomy by the munificence of English Society conducting trade in INDIA with the favour of Baronet CHARLES OAKLEY Commandant Fort St. George A.D. 1792. (English translation by R.C. Kapoor and Dr Ilaria Cristofaro, 2020).

Meanwhile, the pillar has the translations of the Latin inscription in the Tamil, Telugu, English and Persian languages.

A visit to this historic site is a poignant reminder that the Indian Institute of Astrophysics in Bengaluru evolved from this early Observatory.

Figure 10: The 'Monument' at the site of the 1792 Madras Observatory building (photograph: R.C. Kapoor, July 2011).

3.3 Colaba Observatory

In Bombay (present-day Mumbai), the EIC (EIC) took the initiative to start a facility for astronomical observations and time-keeping.

An observatory was established in Bombay in 1826 by the EIC at the southern end of the island of Upper Colaba. The site had been selected in 1823, and the buildings were completed in 1826 under the supervision of John Curnin (d. 1849; Sen, 2014: Chapter 2), the EIC's Astronomer at Bombay since 1822. In fact, Curnin was also the first Astronomer at Colaba Observatory (Field, 1926: 3). The facility (Figure 12) initially consisted of a large transit room and two domes for the purpose of meteorological and astronomical observations and time-keeping (Orlebar, 1846; cf. Gawali et al., 2015: 110). Interestingly, John Curnin had made a request to the EIC to be permitted to buy for the Observatory the equatorial telescope that formerly belonged to King George III (1738–1820), vide the record IOR/F/4/1032/28377 (Date: Mar 1826–Mar 1829) in the "British Library: Asian and African Studies". However, that did not happen. There was a long spell of inactivity as the instruments at the disposal of Curnin were found to be faulty and had to be sent back to England for repairs (Schaffer, 2012: 152).

From 1835, the Observatory also served as a residence for Arthur Bedford Orlebar (1810–1866) who was Professor of Natural History at Elphinstone College that had been founded in Bombay in 1835. There were a few instruments available to Orlebar and systematic observations in astronomy, meteorology and magnetism commenced in late 1841. One

Figure 11: The Latin inscription of the 'Monument' at the Regional Meteorological Centre at Nungambakkam, Chennai (after Alvi, 1976: 10).

Figure 12: Colaba Observatory in 1844, showing the main building with two domes, one hemispherical and the other conical. By this time the non-meridian astronomical functions had been minimized, at the expense of geomagnetism. According to Gawali et al. (2015) the magnetic observations were carried out in the hut which is partially shown at the far left side of the photograph. The lighthouse and dome are seen in the background. This drawing is from the cover of Orlebar (1846).

of Professor Olebar's most important achievements was the establishment of a time ball at Colaba Observatory in 1840 (Samant and Samant, 2016).[2]

Figure 13: Dr George Buist in 1845 (https://www.npg.org.uk/collections/search/portrait/mw00897/George-Buist).

Dr George Buist (1805–1860; Figure 13; Buist, 1849: xli) succeeded Orlebar, and was in charge of the Observatory from January 1842 until March 1845. Despite this short tenure, Dr Buist made a significant contribution through his astronomical observations and writings. For more than a decade he collated information about meteors and meteorites received from many contacts scattered throughout India and from accounts published in newspapers, and he contributed to the series of observations of meteors published in the Annual Reports of the Meetings of the British Association for the Advancement of Science. For several years, these records were prepared by the Reverend Baden Powell, Savilian Professor of Geometry at Oxford, until his last in June 1860, and later they were continued by other astronomers (see Kapoor, 2022). The Great March Comet of 1843 was observed from many locations in India, and in Bombay Dr Buist observed this comet from the Observatory (Kapoor, 2021).

More information about Dr Buist can be found in the dictionary entry by Lane-Pool, (1885–1900). He was a Scottish journalist and also a science teacher. In 1839, he became Editor of *The Bombay Times and Journal of Commerce* and remained with this newspaper for twenty years.[3] It was on the strength of his work that Buist was given responsibility to revive the astronomical, magnetic and meteorological activity at Colaba Observatory in Bombay. He was a member of the Bombay Branch of the Royal Asiatic Society and he published several scientific papers in the Society's Journal. Buist was elected a Fellow of the Royal Society in 1846. His citation on the certificate of election (The Royal Society, 1846) reads:

> The Author of the history of the Afghan War; an Essay upon the Geology of the County of Perth, of various papers in the Journal of the Highland Societies Transactions; on the Geology of Asia; upon a new form of Barometer; on the Meteorology of Bombay &c &c. Distinguished for his acquaintance with the science of Meteorology, Geology & Magnetism; and literature generally.

Buist was also a Fellow of the Geological Society of London, and was the Secretary of the Bombay Geographical Society and the Founder and Resident Superintendent of the Reformatory School of Industry, Bombay.

Charles Chambers was in charge of the Observatory from 1865 until his death in 1896. The Observatory then acquired its first Director of Indian origin in Nanabhoy Ardeshir Framji Moos (1859–1936), who served from 1896 until 1919. Moos established the magnetic observatory at Alibag where observations commenced in 1904, and a time ball on Manora Island, Karachi. Gawali et al. (2015) provide a detailed account of the history, equipment and the important work carried out at the Colaba and Alibag observatories, but also observe that:

> With the onset of digital recording, the instruments once operational at Colaba and Alibag are no longer in use. However, with the passage of time, they have acquired a rich vintage quality. Their preservation should be at the top of the agenda. The instruments from Colaba have been archived at Alibag, the premier magnetic observatory of India. (Gawali et al., 2015: 128–129).

Meanwhile, in reference to Framji Moos, Gawli et al. (2015: 122) pay a glowing tribute:

> His treatise 'Colaba Magnetic Data 1846–1905', published in two volumes, attests to his analytical powers. He meticulously and accurately documented all the observations carried out at Colaba Observatory, interpreting them in his own inimitable style. His insights into the Sun–Earth relationship, which hints at ionospheric currents and a profound conclusion that a small proportion of the Earth's magnetic field owes its origin to sources outside the Earth (Moos, 1910a, b), puts him far ahead of his times.

In 1971, Colaba and Alibag Observatories were formed into the Indian Institute of Geomagnetism, an autonomous institution under the Department of Science and Technology, Government of India.

Figure 14: Radhanath Sickdhar (Wikimedia Commons).

3.4 Calcutta Observatory

At Calcutta, an observatory was established in 1825 by the Surveyor General's Office in Chowringhee at the instance of Valentine Blacker (1778–1826), the Surveyor General of India. Its purpose was to serve the Survey Department. To start with, it had an alt-azimuth circle, a transit telescope, a zenith tube and a Kater's pendulum. Subsequently it came to possess an astronomical telescope. The astronomical observations carried out here included lunar occultations and eclipses of the Jovian satellites. The main activities, however, were time-recording and meteorological observations (Ansari, 2000: 418–419; Sen, 2014: 46–53, 62–63). The first Superintendent of the Observatory was V.N. Rees, who carried out meteorological observations during the period 1829–1852. He was succeeded by Radhanath Sickdhar (1813–1870; Figure 14; Mukhopadhyay, 2014) as the first Indian Superintendent.[4] Sickdhar (also written as Sikdar) systematized the meteorological recordings. The hourly, diurnal and monthly means of the principal weather parameters and rainfall, cloud cover and wind directions as observed at the Calcutta Observatory appeared in the *Journal and Proceedings of the Asiatic Society of Bengal* during 1853–1876.

Figure 15: James Francis Tennant (courtesy: IIAA).

3.5 The Dehra Dun Observatory

Just prior to the 1874 transit of Venus (see Section 4.2, below) the soldier-astronomer Major James Francis Tennant (1829–1915; Figure 15; Hollis, 1916), proposed the establishment of a solar observatory at Shimla, where some of the astronomical instruments supplied by Britain for the transit would be used, but the Government turned him down.

Figure 16: Sir Norman Lockyer in about 1897 (https://archive.org/stream/notablesofbritai00londuoft#page/156/mode/2up).

Shortly afterwards, however, the Government was responsive when the renowned British solar specialist Joseph Norman Lockyer (1836–1920; Figure 16; Meadows, 1972) contacted Lord Salisbury, the Secretary of State for India. As a result, on 28 September 1877 Salisbury wrote to the Viceroy of India:

> Having considered the suggestions made by Mr. Lockyer, and viewing that a study of the conditions of the sun's disc in relation to terrestrial phenomenon has become an important part of physical investigation, I have thought it desirable to assent to the employment for a limited period of a person qualified to obtain photographs of the sun's disc by the aid of the instrument now in India [for the transit]. (*Report …*, 1882).

Kochhar and Orchiston (2017: 747) are convinced that Lockyer either drafted this letter or else provided a detailed briefing paper.

The result was the founding of Dehra Dun Observatory in early 1878, where (weather permitting) daily photographs of the Sun were taken with a Dallmeyer photoheliograph and sent to England for analysis. The hope was that this project would lead to a better understanding of India's enigmatic weather, and particularly the monsoons, which were the lifeblood of the nation's rural communities. The Dehra Dun Observatory was under the auspices of the Survey of India (the new name for the Great Trigonometrical Survey of India).

In 1884 the Hennessey Observatory was erected at Dehra Dun, and the solar photography programme was continued there until 1925, but "… more out of a sense of duty than enthusiasm." (Kochhar and Orchiston, 2017: 748). The Observatory was named after John Baboneau Nickterlien Hennessey (1829–1910; Figure 17), who

> … was appointed to the Indian Trigonometrical Survey in 1844, and in the times of the Mutiny was under arms and on a harassing duty for five months protecting a large number of ladies and children. In 1863, when on leave in England, he entered Jesus College, Cambridge and worked under Profs. Adams, Challis, and Walton to improve his mathematical and astronomical knowledge …

As previously noted by the first author of this paper,

> At the compound of the Survey of India's Geodetic Branch Office in Dehra Dun the Hennessy Observatory still

exists … [see Figure 18] all the instruments are gone, but the dome remains … it and the building require conservation. (Kapoor, 2014: 119).

3.6 Kodaikanal Observatory

In 1882 Madras Observatory Director Norman Pogson proposed the acquisition of a 20-inch (0.5-m) telescope for solar and stellar photography and spectroscopy, and that this new facility should be located at a southern hill station.

This inspired the formation in England of an Indian Observatories Committee, which was charged with assessing the work of Madras Observatory and deliberating upon its future. Given the severe famine in the Madras region in 1876–1877 they focused on the need for solar observations in an effort to better understand monsoonal weather patterns over India, but it was only after Pogson's death in 1891 that the quest for a new observatory was taken up in earnest.

At a meeting of the Committee held in 1893 they decided to establish a new solar physics observatory at Kodaikanal—notwithstanding the existence of the Hennessey Observatory in Dehra Dun. Kodaikanal lay at at an altitude of 2343 m in the Palani Hills in southern India. The decision also was made to transfer all astronomical activities from Mad-

Figure 17: J.B.N. Hennessey (after Phillimore, 1968: 501).

Figure 18: The Hennessey Observatory, Survey of India, Geodetic Research Branch, Dehra Dun (photograph: R.C. Kapoor, February 2013).

Figure 19: A view of Kodaikanal Observatory in 1905 (courtesy: IIAA).

ras Observatory to Kodaikanal and that the new observatory would be under the control of the Central Government.

Kodaikanal Observatory (Figure 19) formally came into existence on 1 April 1899, but construction continued until December 1901 (see Bappu, 2000; Kochhar, 2009). Madras Observatory was left to focus on meteorology, and the only astronomical work that continued there—up until 1931—was conducted in order to provide a time service.

From the start, there was controversy over who would be the founding Director of Kodaikanal Observatory. In the best interests of Indian astronomy the newly knighted Sir Norman Lockyer supported a local candidate, the Professor of Astrophysics at the Government College of Science in Poona, Kavāsjī Dādābhāī Naegamvālā (1857–1938; Ansari, 2019).

Figure 20: Charles Michie Smith (courtesy: IIAA).

Naegamvālā had used a 16.5-in Grubb reflector (later upgraded to a 20-in) for astrophysical research on Galactic objects, but he also had expertise in solar physics with a paper about the sunspot group of February 1892 and his observations of the total solar eclipse of 22 January 1898. He also wrote a monograph about this eclipse (see Section 4.1.5 below). Following the eclipse, Lockyer (1891: 21) stated that in his opinion Naegamvālā was "… the only person in India at that time who was well qualified to carry out worthwhile investigation into solar physics."

Opposing Lockyer was the Astronomer Royal, Sir William Christie (1845–1922; Dewhirst, 2014), who promoted his protégé Charles Michie Smith (1854–1922; Figure 20; Kameswara Rao et al., 2014), Pogson's successor at Madras Observatory in 1891. Smith was born in Scotland (near Aberdeen), and after completing a B.Sc. accepted the Chair of Physics at the Christian College in Madras. There

> … he showed a particular interest in meteor astronomy … [but] apart from observing two solar eclipses during the 1890s there was no hint that he was interested in solar astronomy … (Kochhar and Orchiston, 2017: 753).

Be that as it may, the claims of the expatriate prevailed, and Smith was appointed Director of Kodaikanal Observatory. Up until his retirement, in 1911, he continued to direct both Madras and Kodaikanal Observatories (Anonymous, 1923).

The experienced British solar astronomer John Evershed (1864–1956; Figure 21; Stratton, 1957) joined the staff of the Observatory on 21 January 1907 as Chief Assistant and when Smith retired Evershed became Director. He remained in this post until 1923. He was

Figure 21: John Evershed (right) working with his spectrograph (courtesy: IIAA).

ideally positioned, as the astronomical work at the Observatory focused on solar physics (although other celestial objects did occasionally invite attention).

Kodaikanal Observatory has been an active solar research centre for more than a century. Since 1904, a spectroheliograph has been used to take photographs of the Sun on every clear day in the K-line of ionized calcium. Evershed also introduced another spectroheliograph, for Hα observations. While the former provides information on the upper layers of the chromosphere, the Hα photographs help us learn more about the lower chromosphere.

The wealth of photographic material collected at Kodaikanal Observatory has great archival value since it covers ten entire sunspot cycles, and only Paris and Mount Wilson Observatories have comparable records. The extensive data set spanning such a long interval provides a very good opportunity to study the variation in the solar rotation rate using sunspots and calcium K-line plages, and variation in supergranulation size with solar cycle phase (e.g. see Chatzistergos et al., 2019). In 1934 the Observatory received as a gift a spectrohelioscope from Mount Wilson Observatory which has been used for visual observations of the Sun.[6]

The Observatory was occasionally involved in non-solar research (e.g. on comets), as summarized in its Annual Reports (which are freely available on the website of the Indian Institute of Astrophysics), but the focus throughout has remained on solar studies. One of the highlights from the early years is described below.

3.6.1 The Evershed Effect

On 5 and 7 January 1909 Evershed (Figure 21) obtained the spectra of a sunspot in order to determine the gas pressure in the sunspot, and to his surprise he found that the spectral lines were minutely displaced in the penumbral region (Figure 22). Although other astronomers had previously observed sunspots spectroscopically, this was the first time that such a shift in the lines had been detected. Evershed concluded that these spectral shifts were due to the Doppler Effect, which indicated a radial outflow of solar plasma in the sunspot parallel to the solar surface and with a velocity of about 2 km/sec. This was a major discovery in solar physics, and was named the 'Evershed Effect'.

This was in fact the first astrophysical illustration of interaction between plasma and a magnetic field and it played an important role in our understanding of the physical properties of sunspots and the evolution of solar activity. Much work has been done since then on this

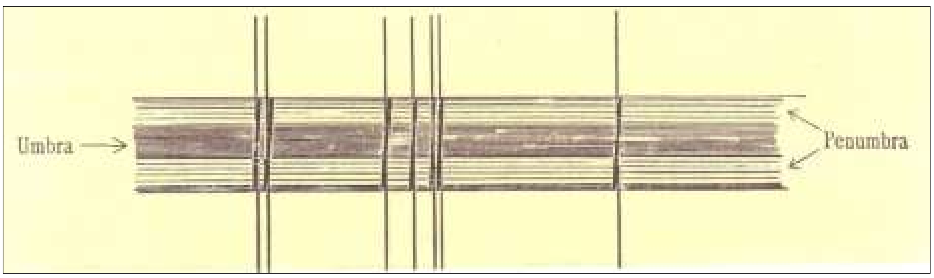

Figure 22: The line sketch by Evershed showing the shift in the absorption line in the penumbra around the sunspot (courtesy: IIAA).

phenomenon in weak photospheric and strong chromospheric spectral lines, especially in Calcium H and K. In particular, the reverse phenomenon of inflow is seen in the chromospheric lines.

January 2009 marked the one hundredth anniversary of the discovery of the Evershed Effect, and the Indian Institute of Astrophysics commemorated this with an international Conference on "Magnetic Coupling Between the Interior and the Atmosphere of the Sun" during 2–5 December 2008; the release of a commemorative stamp and first day cover on 2 December 2008 (see Figure 23) and a Vainu Bappu Memorial (Public) Lecture on 3 December 2008. The conference mainly focused on the critical issues pertaining to solar magnetism and the various magnetohydrodynamic processes in the solar atmosphere, and the current status of magnetic field measurements and their implications for the recent theoretical studies of highly magnetized turbulent plasma in the light of results from space missions like STEREO and HINODE.

Figure 23: The India Post stamp, released on 2 December 2008 commemorating the discovery of Evershed Effect at Kodaikanal Observatory (courtesy: IIAA).

4 ASTRONOMICAL EXPEDITIONS

4.1 Solar Eclipse Expeditions

In the eighteenth century nobody knew of the true physical nature of the Sun, or its corona—which was only visible during a total solar eclipse. We may therefore appreciate how important total solar eclipses were to solar astronomers. Equipped with state-of-the-art equipment, these astronomers were willing to bank on good weather and travel thousands of kilometres to make observations of the corona during the few minutes of totality, in the hope of being able to throw more light on the physics of this complex feature around the Sun.

The first such expedition was led by the Reverend Samuel Williams (1743–1817), a Professor of Mathematics and Natural Philosophy at Harvard, who went to Penobscot Bay in Maine, North America, to view the total eclipse of 27 October 1780 (Rothschild, 2009). From the middle of the nineteenth century, eclipse expeditions became relatively common (Pang, 2002), beginning with the eclipse of 28 July 1851 when the first photograph of the eclipsed Sun was taken on a daguerreotype plate by Johann Berkowski, at Königsberg in Prussia. This showed the corona (Schielicke and Wittman, 2005). Later, the solar eclipse of 18 August 1868 was a 'watershed event' in solar physics, as it led to the identification of hydrogen as the principal component of the chromosphere, prominences and the corona, and the discovery of the element helium (e.g. see Cottam and Orchiston, 2015). Later again, during the twentieth century, expeditions were mounted to test Einstein's Theory of General Relativity: that starlight would be gravitationally refracted as it passed close to the Sun during a total solar eclipse.

While partial solar eclipses were observed from Madras Observatory on 1 February 1813, 16 July 1814, 15 May 1817, 3 March 1825, 4 March 1840 and 21 December 1843, Trivandrum Observatory was the first Indian observatory to mount a total solar eclipse expedition (Caldecott, 1846), in 1843. However, the first solar eclipse that attracted overseas astronomers to India was the 'Great Indian Eclipse of 1868'. This is discussed below, and is followed by accounts of later total or annular solar eclipses that were potentially visible from India during the remainder of the nineteenth century. The primary rationale for British, French and German participation in these eclipse expeditions was to acquire further knowledge about solar physics. The British did not use these Indian eclipses as instruments of colonialism, although they certainly generated enhanced awareness of the complex links between solar radiation and India's fickle monsoonal weather. This in turn led, eventually, to the founding of Dehra Dun Observatory and its successor the Hennessey Observatory, as we saw in Section 3.5 above.

4.1.1 The Great Indian Total Solar Eclipse of 18 August 1868

The path of totality of this eclipse extended from Aden in the West through to Melanesia in the East (Figure 24), and with totality lasting an unusually long 6 minutes 47 seconds, this was a particularly attractive research proposition. But what astronomers also found appealing was the fact that this particular eclipse occurred at a critical time in the worldwide evolution of astronomical instrumentation. Thus, for the very first time during a total solar eclipse, the chromosphere, prominences and the corona could be subjected to simultaneous photographic, polariscopic, spectroscopic and visual scrutiny.

As a result, colonial expeditions from England, France and Germany were attracted to this eclipse, and they were sited in Aden; right across southern India; and in Siam, or present-day Thailand (see Orchiston and Orchiston, 2017). Meanwhile, expeditions mounted by locally-based Western or Indigenous astronomers were found in India (as we shall see), Siam (Orchiston and Orchiston, 2021; Soonthornthum and Orchiston, 2021) and the Dutch East Indies (Mumpuni et al., 2017; Orchiston, et al., 2021b). In this paper we will restrict ourselves to observations made from India.

As Director of India's leading observatory, Norman Pogson had grand plans to observe this eclipse from four different locations, but he had not allowed for interference by the Astronomer Royal, George Biddell Airy, whose animus towards Pogson dated back decades. Instead, Airy supported a 'British eclipse expedition' led by ex-Trigonometical Survey of India soldier-astronomer, Major James Francis Tennant (who for one year was the stand-in Director of Madras Observatory immediately prior to Pogson's appointment). Tennant received equipment and support from the Royal Observatory and Royal Astronomical Society, and was able to mount a successful campaign (Tennant, 1869; cf. Orchiston et al., 2017) while based at Guntoor (site number 2 in Figure 25).

Airy also supported two formal Trigonometrical Survey of India eclipse expeditions, one based at Jamkandi (site 5 in Figure 25) and led by Lieutenant John Herschel (1837–1921), a son of Sir John Herschel, and the other led by Captain C.T. Haig from the Royal Engineers, and sited at Bijapur (site 4 in Figure 25). Both successfully observed the eclipse (see Herschel, 1869; Tennant, 1869).

Without official support from Airy, and with restricted access to Indian Government funding, Pogson was only able to mount two eclipse expedition, one based at Masulipatam (site 1 in Figure 25) which he led, and the other led by his First Assistant Ragoonatha Charry (Figure 9), who was based at Vunpurthy (site 3 in Figure 25). But even then, Pogson (1869) had to draw on meteorological funding in order to mount the expeditions, and call on assistance from friends in England to fully resource them. Astrophysics pioneer, William Huggins, loaned him two telescopes, a spectroscope, a polariscope and a micrometer, while he received a third refracting telescope from Dr John Lee (his former employer, at Hartwell House Observatory). These instruments and other instruments from Madras Observatory were shared between Masulipatam and Vunpurthy

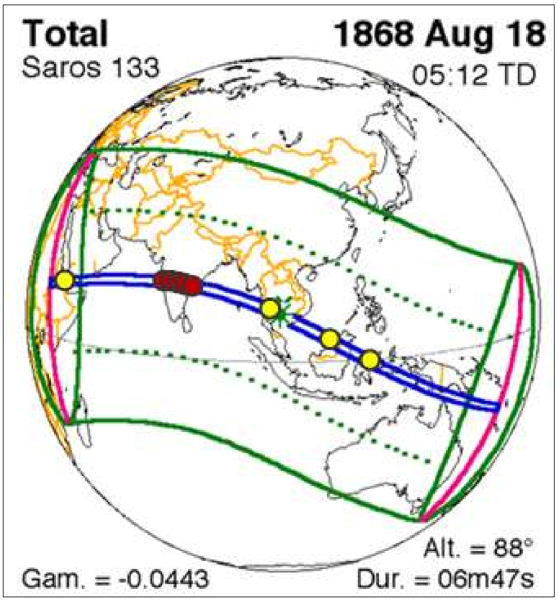

Figure 24: The path of totality of the 18 August 1868 total solar eclipse showing sites were observing teams were located; those in India are in red (base map after Espenak and Meeus, 2006; map modifications: Wayne Orchiston).

Pogson (1868: 3–4) gave the geographical position of his eclipse station as 16° 11' 33" North, and the longitude as 5h 24m 46s East, based on the position of the Masulipatam Flagstaff. Just before totality commenced, Pogson saw the Baily's Beads and a few prominences. He also drew views of the eclipsed Sun just

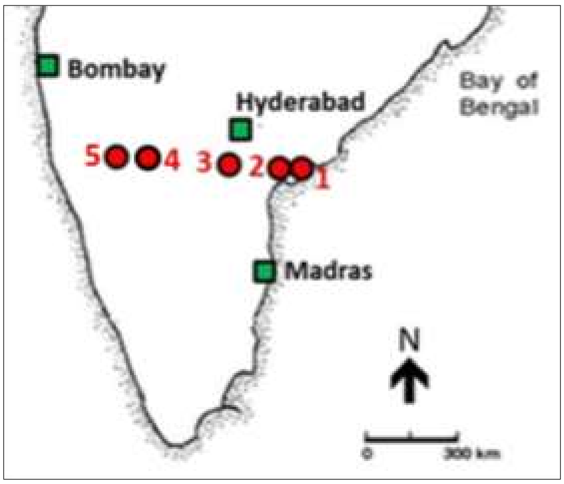

Figure 25: Sites where expeditions were based for the 18 August 1868 total solar eclipse. Key: 1 = Masulipatam; 2 = Guntoor; 3 = Vunpurthy; 4 = Bijapur; 5 = Jamkandi (map: Wayne Orchiston).

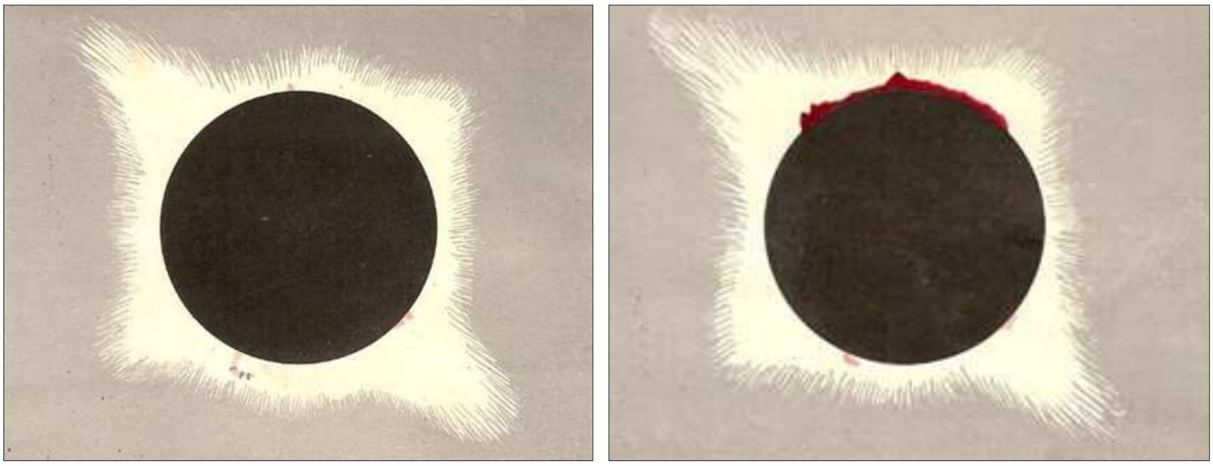

Figure 26: Pogson's sketches of the solar corona and the prominences during totality (courtesy: IIAA).

after its disappearance and before its reappearance, showing an asymmetrical corona and the prominences (Figure 26). One of these rose-coloured prominences was quite long, and conspicuous to the naked eye, and Pogson (*ibid.*) measured its height as about 199.4 arcsec, equivalent to 88,352 miles. He recorded the eclipse circumstances, including the contact timings of the four main sunspots. The corona

> … was of a pure white silvery nebulous nature for two or three minutes of arc from the moon's limb, when its homogeneous appearance ceased, and it seemed to radiate from the Sun's centre until lost in the surrounding hazy sky. (Pogson, 1869: 6).

He also caught glimpses of Venus, Mercury, Castor and Pollux, and probably Orion.

But without doubt, Pogson's most important observations were made with the Huggins spectroscope when he recorded the presence of a new emission line, close to, but not identical to, the yellow D-line of sodium. Pogson (*ibid.*) describes this momentous discovery:

> I have now to treat of the Spectroscope, the new and deservedly popular instrumental wonder of the age, the application of which to the examination of the nature of the corona and red prominences, gave to this eclipse so extraordinary and fictitious an amount of interest. By the kind aid of the distinguished astronomer to whom science is indebted for the development of this new branch of research, W. Huggins, Esq., of London, I was placed in possession of an excellent spectroscope, constructed by Messrs. Troughton and Simms under Mr. Huggins' special superintendence. Unfortunately, it did not reach Madras until July 6th, and had then to be adapted to the telescope upon which it was to be used for the eclipse. This was a five-foot, made up at the Public Works Department, with the four-inch object glass, by Dollond, formerly used in the old Transit instrument of the Observatory, mounted on a firm portable equatoreal stand by Messrs. Cooke and Sons. The weight of the spectroscope was considerable, rendering counterpoising and adapting, so as to secure perfectly smooth tangent rod motion, far from easy. (Pogson, 1869: 9).

The sketch of the solar spectrum that Pogson made at the time is shown in Figure 27, where the most conspicuous solar emission lines are shown in the upper black strip, and the reference spectrum is below. A detailed account of Pogson's discovery of helium is presented by Nath (2013) in his book *The Story of Helium and the Birth of Astrophysics*, and a summary is provided by Nath and Orchiston (2021).

The other important discovery that Pogson made was the green spectral line Kirchoff 1474, which is now known to be associated with highly ionized iron (Fe XIV), at 5303 Å (530.3 nm). Pogson (1869: 10–11) reports:

> A little before 9 A. M., when the partial phase was well advanced, I turned the spectroscope upon the Sun, and took the micrometer readings of seven known lines of the ordinary spectrum, agreeably to Mr. Huggins' instructions. I had previously taken care to have the equatoreal stand in tolerable adjustment, and side by side with the Smythian telescope employed for the other class of observations. After measuring the long prominence, as before

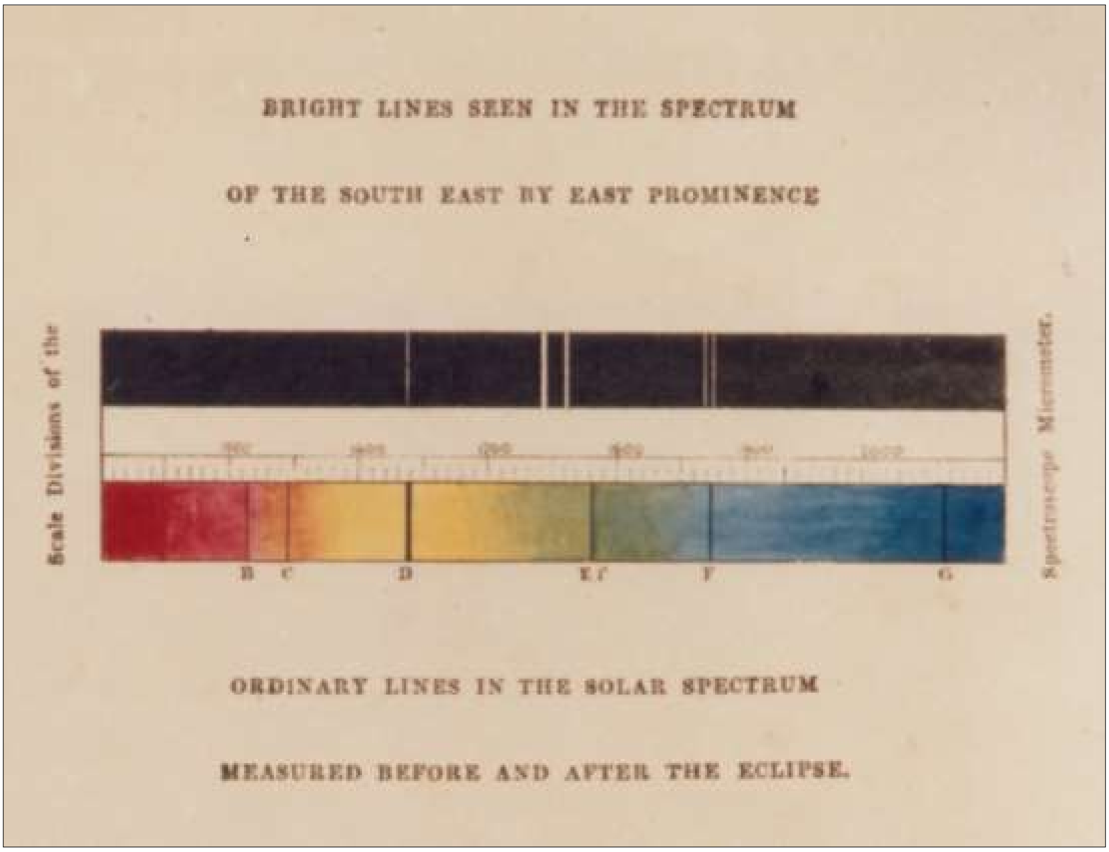

Figure 27: Pogson's hand-coloured sketch of the solar spectrum during the total solar eclipse of 18 August 1868 (courtesy: IIAA).

> described, about one minute after the beginning of totality I directed the finder of the spectroscope telescope to a part of the corona on the sun's southern limb, as clear of any visible prominences as possible. A faint light was seen, scarcely colored, and certainly free from either dark or bright lines. While wondering at the dreary blank before me and feeling intensely disappointed, some bright lines came gradually into view, reached a pretty considerable maximum brilliancy, and again faded away. Five of these lines were visible, but two decidedly superior to the rest. A turn of the right ascension tangent rod immediately brought back the welcome lines, and by manipulating it with one hand and the spectroscope micrometer with the other, the readings of the two brightest were secured. It struck me as strange that these brightest lines should appear at a part of the spectrum not corresponding to any very conspicuous dark lines in the solar spectrum, but not having Kirchhoff's chart in my possession, I must leave it for my scientific friends at home to decide upon the interpretation of the measures obtained. The third line seen, in order of brilliancy, must have been either coincident with, or very near the place of the sodium line D, but it was much fainter than the two measured; while the fourth and fifth lines were extremely faint, and about as close as E and f, but I estimated them to be somewhere near the position of Fraunhofer's F in the solar spectrum, The fact of bright lines being seen at all, shews that the red prominence which produced them was composed of incandescent gas, but whether similar to any of our known terrestrial elements or otherwise it would be premature for me to offer any opinion.

This same emission line was seen by C.A. Young during the eclipse of 7 August 1869, and later attributed to a new element that was named 'Coronium'. Pogson had already seen the line in the eclipse of 18 August 1868 but other astronomers were unaware of this because his report was not circulated worldwide.

Polarization observations also were made at Masulipatam, by G.K. Winter (a telegraph engineer from the Madras Railway), and the

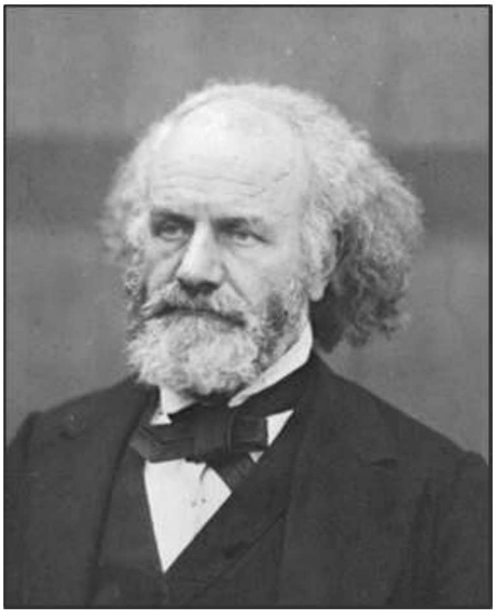

Figure 28: Pierre Jules César Janssen (https://observations-solaires.obspm.fr/Jules-Janssen).

Figure 29: The Janssen–Lockyer Medal showing the profiles of the two scientists and Apollo's chariot passing in front of the Sun (after Launay, 2021: 120).

polariscope showed that the light of the corona was polarized implying that it was reflected sunlight. Winter (1869: 21) wrote that

> The plane of polarization being everywhere radial to the sun, makes it as certain that its light is derived therefrom. This being so, from the great amount of polarization observed, we may conclude that the corona is caused by an atmosphere surrounding the sun and reflecting the solar light.

Ragoonatha Charry was based at Vunpurthy, and he used double altitude measurements of γ Draconis to determine that the latitude of his observing site was 16° 22′ 18″ N. However, finding the longitude was a different story:

> As I had no other means of finding the longitude of Vunpurthy, I assumed the mean daily rate of the best chronometer to be uniform throughout the interval between my departure from and return to Madras. (Pogson, 1869: 24).

Sadly, on the day of the eclipse, the sky clouded over, and Charry could only make a few observations.

Apart from the aforementioned 'British' eclipse parties, there was a German expedition led by Professor Friedrich Tietjen (1834–1895) from the Astronomisches Rechen-Institut, based at Mulwar, near Bijapur (site 4 in Figure 25).

Finally, near Tennant's camp at Guntoor was a French eclipse party, led by the famous solar physicist Pierre Jules César Janssen (1824–1907; Figure 28; Launay, 2012). Although he was experienced in spectroscopy, during the eclipse Janssen mistook the yellow emission line for sodium, and it was only later, after re-examining his observations and discussing them with Lockyer, that they realised this must be a new emission line (they knew nothing of Pogson's discovery). Lockyer (Figure 16) then coined the term 'helium' for the new element, and in 1872 the Académie des Sciences in Paris issued a special medal to commemorate this important discovery (see Figure 29). This 'discovery' sparked a life-long friendship between Janssen and Lockyer, but as Launay (2021) has shown, Janssen never claimed to have discovered helium during the Indian eclipse (even though he is often given credit for this). Meanwhile, it was only in 1895 that Sir William Ramsay (1852–1916) detected helium in the laboratory, thereby proving that it was indeed a terrestrial element and not just confined to the Sun.

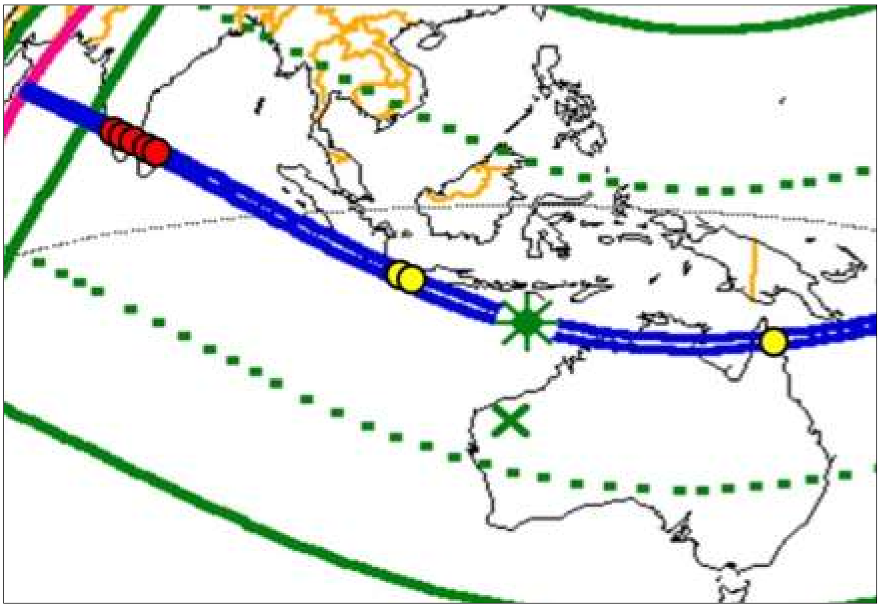

Figure 30: The path of totality of the 11 December 1871 total solar eclipse showing sites where observing teams were located; those in India are in red (base map after Espenak and Meeus, 2006; map modifications: Wayne Orchiston).

Why was it that other astronomers were unaware of Pogson's discoveries at Masulipatam? Late in 1868 Pogson wrote a 32-page report on the observations of the eclipse made at Masulipatam, Vunpurthy, Madras and other stations in Southern India, in which he announced the major results, including discovery of the two new spectral lines. Pogson addressed this report to R.S. Ellis, the Chief Secretary to Government at Fort St. George. After lengthy and totally inexplicable delays only three copies of the report were published (Pogson, 1869), instead of the multiple copies that were anticipated, which were to have been distributed to all of the major observatories of the world, and especially those involved in solar physics. This is why Pogson's discoveries remained largely unknown, until they were unearthed by Professor Biman B. Nath in the course of researching his book on the discovery of helium.

Nath found that Pogson's 1869 report not only discussed his own observations, but also those of other astronomers, and that Pogson was always happy to assign credit when credit was due:

> A further and highly important fact was also realized, viz., that the red prominences could at any time be examined, without waiting for an eclipse at all. That such was possible was an idea entertained by many astronomers, and often attempted, though unsuccessfully, by the few in possession of the necessary appliances; but it remained for M. Janssen, the French savant, at Guntoor, and Mr. Norman Lockyer, in England, to accomplish the feat, and thereby to enter upon a new and most interesting investigation of the physical nature of the sun, substituting facts and instrumental precision for the vague conjectures and hypotheses hitherto hazarded upon such points. (Pogson, 1868: 3).

For further details of Indian observations made during this famous eclipse see Launay (2021), Nath (2013), Nath and Orchiston (2021), Orchiston et al., (2017) and Venkateswaran (2021).

4.1.2 The Total Solar Eclipse of 11 December 1871

About three and a half years after the groundbreaking 1868 eclipse India was favoured with another total solar eclipse, on 12 December 1871. The path of totality crossed southern India, Ceylon (now Sri Lanka), the island of Java in the Dutch East Indies (currently Indonesia) before crossing northern Australia and expending out into the Pacific Ocean (see Figure 30). Observing parties were based in all of these locations, and while those in Java made successful observations (Mumpuni et al., 2017) the sole Australian site was clouded out (Lomb, 2016).

Having another total solar eclipse in India so soon after the success of the 1868 event meant that overseas expeditions again flocked to India in 1871. Generously funded by the

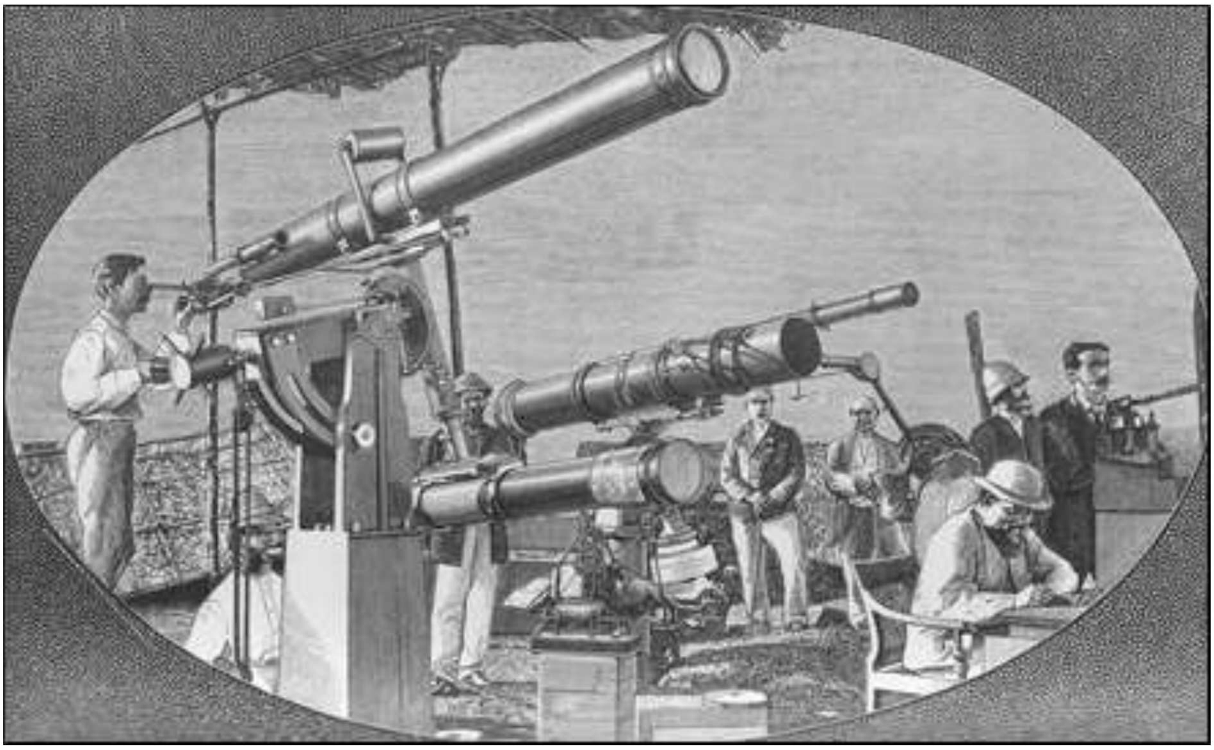

Figure 31: Some of the instruments at Bekul ready for the 1871 eclipse (after Lockyer 1874: f343).

British Government, Norman Lockyer (1874) led a team of nine astronomers, and they carried out successful observations from Bekul (Figure 31), Poodocottah and Manatoddy in India (see Figure 32) and from two sites on the neighbouring island of Ceylon. Lockyer was one of Britain's most respected scientists, and he enjoyed a high public profile. This was his first visit to India, and the exotic nature of his expedition appealed to the public back in England, where it featured in the pages of *The Illustrated London News* (e.g. see Anonymous, 1872a).

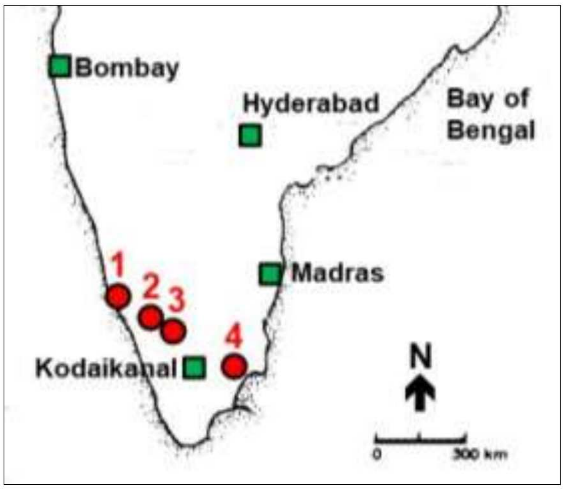

Figure 32: Sites where expeditions were based for the 11 December 1871 total solar eclipse. Key: 1 = Bekul; 2 = Manatoddy; 3 = Avenashi, Dodabetta Peak, Ootacamund and Sholur 4 = Poodocotta (map: Wayne Orchiston).

As might be anticipated, given their successes in 1868, the 1871 eclipse also attracted Lieutenant John Herschel and Major James Tennant (1872; 1875), who joined forces and carried out successful observations from Dodabetta Peak, near Ootacamund (see Figure 32).

The French also were back in India for this eclipse, with the ever-familiar and popular Jules Janssen (1873) based at the village of Sholur in the Nilgiri Hills, near Ootacamund (Launay, 1997; Mahias, 2010). Notwithstanding their friendship it is notable that none of Lockyer's eclipse camps was near to Janssen's compound.

Meanwhile, the Italians did not want to miss this eclipse, so the Director of the Astronomical Observatory at Campidoglio in Rome, Lorenzo Respighi (1824–1889; Herbermann, 1913b) was Lockyer's neighbour at Poodocottah (Janssen, 1873).

Nor could Madras Observatory miss this fine opportunity, and Pogson mounted a successful eclipse expedition (see Figure 33), using an observing site at Avenashi, which was also near Ootacamund. On this occasion, he was joined by his son, C. Ragoonatha Charry, Colonel Rutherdon, Mr Doderet and Mr Winter. Months before the eclipse, Ragoonathacharry (1871) published detailed calculations of the central and limiting lines of the shadow, and circumstances of the eclipse over principal

Figure 33: Norman Pogson around the time of the December 1871 total solar eclipse. He is the bearded man second from the right. The man with the white turban fifth from the right appears to be Ragoonatha Charry (adopted from Kameswara Rao et al., 2009).

places in Karnataka and Tamil Nadu, especially those situated close to the line of totality.

Between them, the various Indian-based and overseas eclipse expeditions carried out successful photographic, spectroscopic, polariscopic and visual observations on eclipse day. This is indicated in a telegram that Pogson sent to Airy on 12 December, which subsequently was published in *The Astronomical Register*:

> From N. R. Pogson, Esq., at Avenashy, to the Astronomer Royal, Royal Observatory, Greenwich.
>
> Weather fine. Telescopic and camera photographs successful. Ditto polarisation. Good sketches. Many bright lines in spectrum.
>
> Dec. 12th. (Anonymous, 1872b: 8).

The combined results from all of these observations consolidated those obtained in 1868, but one area of special interest was the 'coronium line' at 1474 K. As we know, Pogson had discovered this in 1868, but other astronomers were unaware of this and assigned the credit to Professor Charles Augustus Young (1834–1908; Frost, 1910) who independently detected the line during the 7 August 1869 eclipse (Maunder, 1899). The other notable achievement was that when photographs obtained by Tennant and Davis were combined they provided exquisite detail of coronal structure (e.g. see Figure 34).

Orchiston and Pearson (2017: 808) concluded that "The 1871 total solar eclipse … therefore built on India's reputation as a place

Figure 34: A combination of images of the 1871 eclipse obtained by Tennant and Davis, showing fine coronal detail (after Ranyard, 1879: plates).

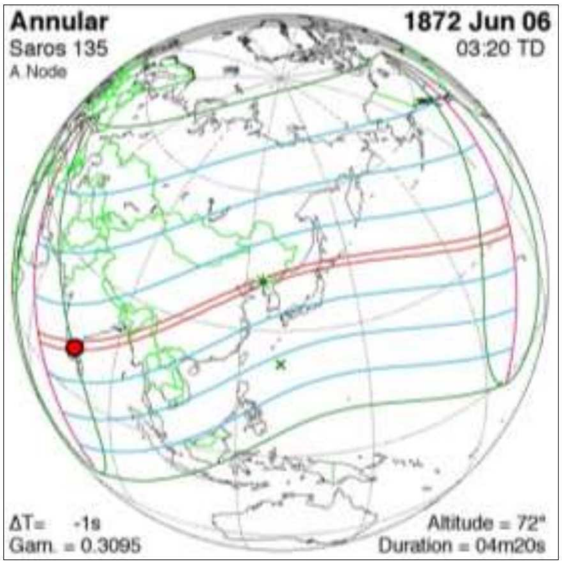

Figure 35: The ant-umbral path of totality of the 6 June 1872 annular solar eclipse, with Pogson's observing site, in red, near the Southern tip of India (after Espenak and Meeus, 2006).

that could contribute in a meaningful way to solar science." Like its 1868 predecessor, this eclipse was solely about solar physics research, and played no part in Britain's colonial ambitions.

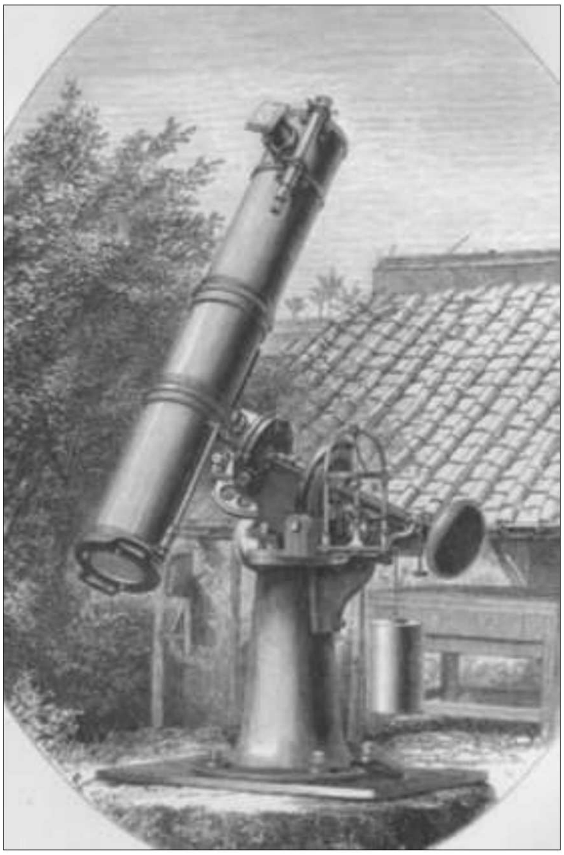

Figure 36: The equatorially mounted 9-inch Newtonian reflector that Pogson used to observe the 1872 annular eclipse (after Tennant, 1869: 51).

4.1.3 The Annular Eclipse of 6 June 1872

The path of the annularity of this eclipse passed over the southern tip of India (Figure 35). Because it was not a total solar eclipse and because annularity was of short duration (only 1 minute and 14 seconds) it did not attract overseas eclipse parties to India or even astronomers from the Trigonometrical Survey of India. The only astronomers interested in observing this event were from Madras Observatory. Yet in his one short published paper about their observations Pogson (1872) fails to reveal the location of their eclipse camp.

What he does do, though, is indicate that the eclipse party included his son, Ragoonatha Charry and Mr F. Doderet; that they made photographic, spectroscopic and visual observations; and that Airy sanctioned Pogson's use of "… the Browning reflector …" (Pogson, 1872: 330). This can only be the 9-inch (22.9-cm) equatorially mounted Browning–With Newtonian reflector that Airy supplied for Tennant, and which he used so effectively to photograph the prominences from Guntoor during the 1868 eclipse (Orchiston et al., 2017). This telescope is shown in Figure 36, set up for photography at Guntoor, and Pogson (1872: 330–331) describes its use during the 1872 eclipse:

> Availing myself of your kind encouragement to make use of the Browning reflector, I got the Government to sanction the immediate erection of a sliding flat-roofed room, a dark room, and a printing room, over the transit-circle room, and got all completed just, and only just, in time. My son, assisted by Mr. F. Doderet, got nine photographs altogether—four during the important time. I enclose copies of six: No. 1, partial, before centre; 2, just as the ring was forming, when the coronal light, shining behind the Moon's disk, made the ring appear faintly completed before it really was so. This was clearly seen also by Ragoonatha Charry with the Lerebours equatoreal, and even by myself and my son with the finders of the Simms' equatoreal and of the Browning reflector. The photograph shows it, but the negative better still. No. 3 shows the complete ring at central time, 4 near its breaking, 5 at the moment, and 6 a partial phase soon after. Nos. 4 and 5 got taken on the same plate by a mistake, but, by placing one in the centre and painting the other out, there is no confusion.

During his observation of this eclipse Pogson also recorded the flash spectrum of the Sun. This was the first time that the reversal of the solar spectrum (the flash spectrum) was seen during an annular eclipse. Previously, it had only been seen during total eclipses. The flash spectrum was first recorded by Dartmouth College's Professor Young during the eclipse of 22 December 1870. Pogson (1872: 331) reported on his own observations:

> I resolved to attempt nothing but the spectroscope and … wanted to have had the time of first contact from the spectroscope, by the extinction of the usual bright C, D, and F lines of the chromosphere. I can rarely find any part of the Sun's limb on a fine day at which these are not visible, and I thought that the contact of the limbs should extinguish these ... At the first internal contact (just after a peep in the finder had shown me the Moon's limb lighted up by the corona) I saw all the dark lines reversed and bright, but for less than two seconds; the thinnest thread of sunlight restored them instantly … The sight of beauty, above all, was, however, the reversion of the lines at the breaking up of the limb … The duration astonished me — five to seven seconds; and they faded out gradually, not momentarily.

Pogson (1872: 331) also noted that no prominences were seen, either visually or on the photographs, even though "… the spectroscope indicated plenty about, especially near the spot shown in [photograph] No. 4."

4.1.4 The Total Eclipse of 22 January 1898

The final nineteenth century total solar eclipse that drew international astronomers to India occurred on 22 January 1898, with the path of totality extending from Africa, across central India, to Mongolia (Figure 37). Expeditions from England, Japan, Scotland and the USA all made their way to India.

As Figure 38 indicates, observing teams were located at nine different localities. There were four official British Government expeditions, sponsored by the Joint Eclipse Committee of the Royal Society or the Royal Astronomical Society (Christie, 1898). One of these was led by Astronomer Royal William Christie and Oxford University's Herbert Hall Turner (1861–1930; Plummer, 1931), who were based at Sahdol (site 2 in Figure 38).

A second expedition was led by soldier-astronomer Captain Edmond Herbert Grove-Hills (1864–1922) and Cambridge University's Hugh Frank Newall (1857–1944; Hearnshaw, 2014). They carried out successful spectroscopic observations from Pulgaon, which is site 4 in Figure 38 (see Grove-Hills and Newall, 1898).

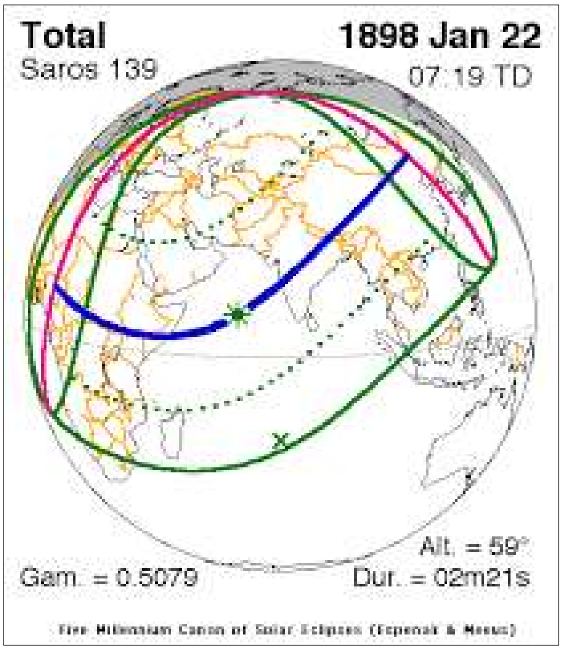

Figure 37: The path of totality of the 22 January 1898 total solar eclipse after Espenak and Meeus, 2006).

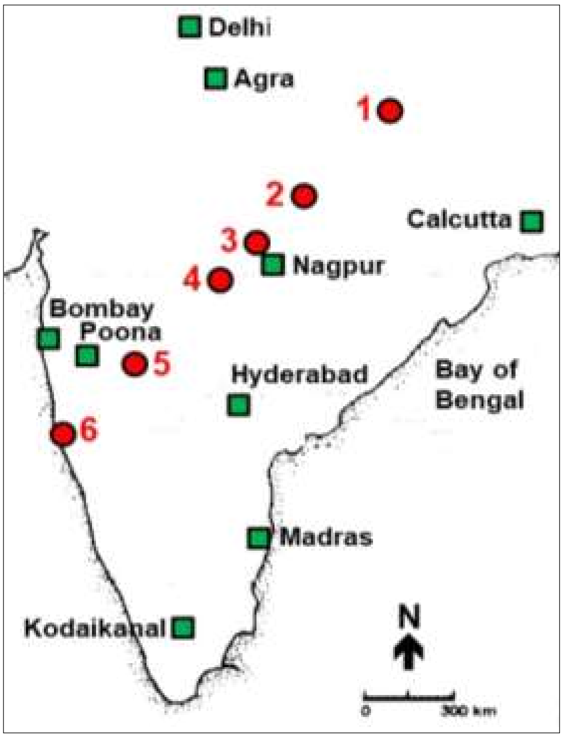

Figure 38: Sites where expeditions were based for the 22 January 1898 total solar eclipse. Key: 1 = Buxar and Dumraon; 2 = Sahdol; 3 = Ghoglee, 4 = Pulgaon and Talni; 5 = Jeur and Vangi; 6 = Viziadurg (map: Wayne Orchiston).

Figure 39: A scene showing the Lick Observatory party ready for the eclipse. All of the instruments are in place and the volunteers are at their practice stations. The 40-ft Schaeberle Camera with its twin wooden towers dominates the scene (courtesy: Mary Lea Shane Archives).

Christie (1898) indicates that Sir Norman Lockyer and Alexander Pedler (1849–1918), Director of Public Instructions in Bengal, led a third expedition, and they observed the eclipse from a British ship that was anchored at Viziadurg (site 6 in Figure 38).

The fourth official expedition was a 2-man Scottish party led by the Astronomer Royal of Scotland, Dr Ralph Copeland (1837–1905; Marché, 2014). They were based at Ghoglee, 16 km north-west of Nagpur (site 3 in Figure 38), where they carried out successful photographic and spectroscopic observations (Copeland, 1898).

In addition, Britain was represented by the British Astronomical Association (BAA), which mounted an ambitious expedition

> … using two observing sites, and in a copiously-illustrated 184-page book, Edward Maunder (1899) provides a detailed account of this venture by some of Britain's leading amateur astronomers … One of the BAA camps was at Talni … where Maunder (1851–1928; Baum 2014) and John Evershed (1864–1956; Stratton 1957) carried out spectroscopic observations … while the other was at Buxar … where successful photographic observations were made … (Orchiston and Pearson, 2017: 808).

Buxar and Talni are sites 1 and 4, respectively in Figure 38.

One of the two international expeditions based at Jeur (Site 5 in Figure 38) was a Japanese team from Tokyo University led by Professor Hisashi Terao (1855–1923; Terao and Hirayama, 1910). The other was the ambitious Lick Observatory expedition, led by William Wallace Campbell (1862–1938; Wright, 1949). Successful photographic and spectroscopic observations were made (Campbell, 1898; 2000), the former with the impressive-looking 40-foot Schaeberle Camera (Figure 39; Pearson and Orchiston, 2008), which revealed the fine structure of the solar corona. Further details of the Lick Observatory expedition are provided in Orchiston and Pearson (2017) and Pearson et al. (2011).

Meanwhile, a small US party from the Chabot Observatory was based at Vangi (site 5 in Figure 38) and was led by Charles Burkhalter (1898), who focussed on photographing the corona.

We now come to Indian expeditions, and there were two, neither from Madras Observatory. One was led by Professor K.D. Naegamvālā (Figure 40) from the College of Science in Poona and was at Jeur, very close to the Lick Observatory's camp. Naegamvālā used the horizontal photoheliograph shown in Figure 41 to obtain a photograph of the 'flash' spectrum (Naegamvala, 1898) and images of the corona. Naegamvālā (1902) subsequently published his results as a monograph. For a detailed account of Naegamvālā's life and astronomical research, including his 1898 solar eclipse project, see Ansari (2019).

The second all-Indian expedition was from St. Xavier's College in Calcutta and led by the Jesuit, Father Vincent de Campigneulles (1847 –1917; Udias, 2003). They were based at Dumraon (site 1 in Figure 38) and photographed the Sun (Chinnici, 1996/96: 109, n.48). Their observations are discussed in de Campigneulles and Jasson (1898) and de Campigneulles (1899).

What of Madras Observatory? Did they decide to miss this eclipse? The answer is "no quite", for Michie Smith joined the BAA party led by Maunder and Evershed that conducted spectroscopic observations from Talni (see Maunder, 1898, 4−28). Fate decreed that almost a decade later Evershed would come to India again, and join Mitchie Smith at Kodaikanal Observatory. As we have seen, he subsequently inherited the Directorship.

The foregoing review illustrates that

> The 1898 solar eclipse offered one final opportunity to build on the legacy established in 1868 and 1871 and contribute to the rapidly-accumulating international knowledge of the solar corona. (Orchiston and Pearson, 2017: 808).

Figure 40: Professor K.D. Naegamvālā (after Kameswara Rao et al., 2014: 450).

As a final comment on the nineteenth century Indian solar eclipses we should note that the Joint Eclipse Committee of the Royal Society and Royal Astronomical Society also decided to use the 1898 eclipse as an opportunity to report on the status of India's colonial observatories. Thus, apart from observing the eclipse, Christie toured India, visited Bombay, Madras and Kodaikanal, and then prepared a 17-page report, an abbreviated version of which was published in the *Proceedings of the Royal Institution* (Christie, 1898). Meanwhile, Lockyer (1898) quite independently used his eclipse visit to write a report on the Indian observatories, at the request of the India Office in London.

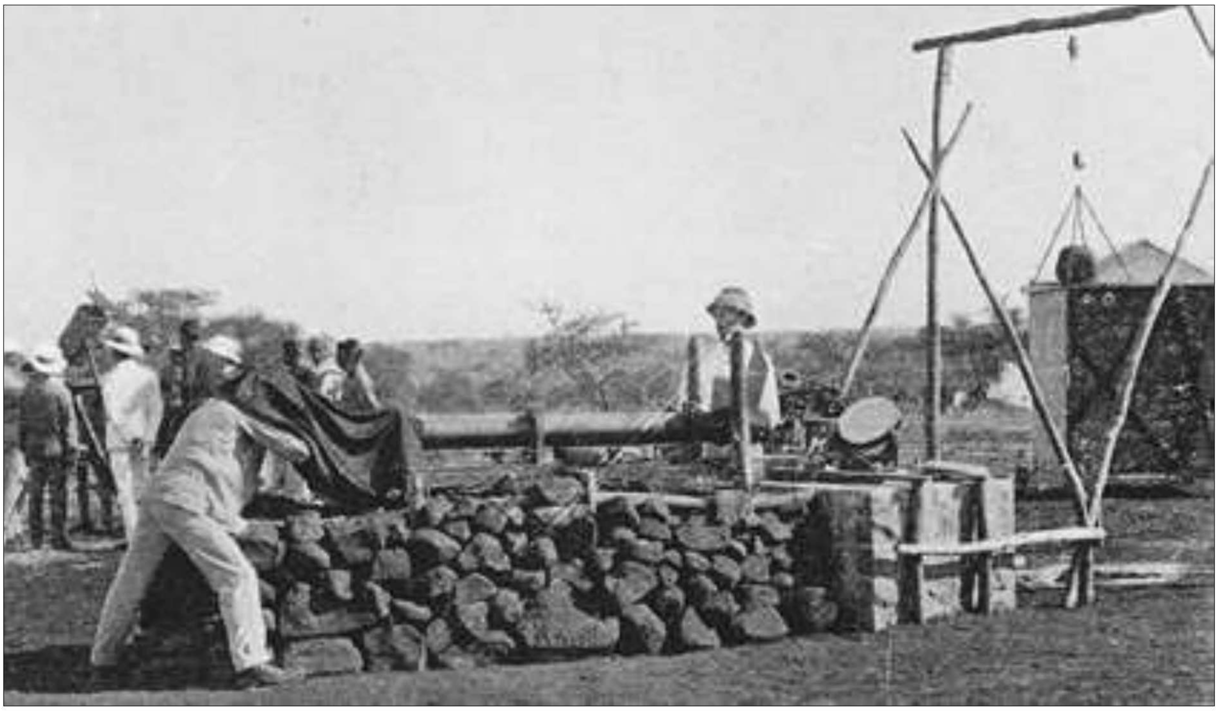

Figure 41: Professor Naegamvālā's horizontal photoheliograph at Jeur in 1898 (after Maunder, 1899: 81).

4.2 The 1874 Transit of Venus

As indicated at the end of Section 2.2.1 above, the 1874 transit of Venus would be of prime importance to India.

Largely as a result of changes in technology, the upcoming 1874 and 1882 transits gave rise to widespread excitement worldwide. Observatories braced themselves for the observations, and numerous expeditions to far-off lands were planned. The 1874 event would be the first transit observed using photography and spectroscopy.

In India, the plan was to observe the 9 December 1874 transit from several different localities. Among these, Madras Observatory was the most prominent institution that was suitably equipped for the occasion. In comparison, Colaba Observatory in Bombay had fewer suitable instruments. Observations were planned also at the headquarters of the Great Trigonometrical Survey in Dehra Dun.

The interest and the preparatory activity can be gauged also from the references to the forthcoming transits at meetings of the Asiatic Society of Bengal during 1873 and 1874. At its meeting of February 1873, in his Presidential Address T. Oldham, Esq., LL.D. (1816–1878), impressed upon the members how significant the observations of these rare events would be, which were planned to be carried out from regular and makeshift observatories at various places around the world, and that

> … the Government of India have, on representations made to them of the value of a series of observations especially photographic in the clearer atmosphere of some high elevation in North India, at once sanctioned the necessary expenditure for instruments, and have telegraphed for their immediate preparation. In connection with this, the General Committee of the British Association at their meeting in 1872, August last, requested the Council to take such steps as seemed desirable to urge the Indian Government to prepare these instruments, with the view of assisting in the Transit of Venus in 1874. (*Proceedings of the Asiatic Society of Bengal*, 1873: 58–62).

The British Association urged the Government of India to establish a solar observatory, and suitable locations for it existed in the mountain ranges (*Proceedings of the Asiatic Society of Bengal*, 1873; 1875). Colonel H. Hyde (Royal Engineers), who succeeded Dr Oldham as the President of the Society, in his address at the February 1874 Meeting, stated that

> In India, however, Spectroscopic observation is making some progress in the Department of the Great Trigonometrical Survey and the atmospheric lines of the Solar Spectrum are being observed. Mr. J.B.N. Hennessey has continued observing and mapping the atmospheric lines of the Solar Spectrum, employing in supersession of the instrument formerly used, an excellent three-prism (compound) spectroscope with automatical adjustment belonging to the Royal Society of London. This instrument is placed at a height of about 6,500 feet above sea level, on a projecting spur of the Himalayan range on which the Sanitarium of Mussoorie is located, so that a clear view is obtained of the Sun down to the very horizon … (*Proceedings of the Asiatic Society of Bengal*, 1875: 46–48).

A brief account of the observations of the transit from various other stations in India is given in Markham (1878: 339–340).

Staff at Madras Observatory made elaborate arrangements to observe the transit, but clouds frustrated most of these efforts. Therefore, the Observatory has no publications about the observations, except for a brief account that forms part of the Administration Report of the Observatory for 1874, and a letter by Pogson (1875) to *The Astronomical Register* where he reports on the failure, but also stresses the importance of determining the solar parallax from observations of Mars when it is at opposition.

Long before the transit was to take place, Pogson was concerned that it be observed from various sites in India. Despite the failure of the Madras Observatory observations due to bad weather, Pogson provided valuable help to observers stationed elsewhere through telegraphic determination of their respective longitudes, which, in his own words was,

> … one of the most important and yet the most difficult of all the requisite data for rendering their observations available for the determination of the solar parallax. (Pogson, 1874: 2).

Telegraph lines from London to India had been laid and connected only recently, in January 1870, first to Calcutta and then to Bombay and Madras (see Karbelashvili, 1991). Pogson's longitude work subsequently was published (see Pogson, 1884).

In 1874, as the transit date drew nearer, Pogson's First Assistant Ragoonatha Charry, prepared a 38-page booklet titled *Transit of Venus* which was written in English, Kannada, Urdu and other languages (Shylaja, 2012). Through several figures, the booklet beautifully explained the transit to the lay public.

Markham (1878: 339–340) writes that J.B.N. Hennessey (Figure 17) from the Great Trigonometrical Survey observed the transit from Masauri (Mussoorie) in the Shivalik Hills, 6765 ft above mean sea level. Hennessey's main objective was to observe the transit from a high altitude, hence his decision to locate his observing station near Mussoorie. He used an equatorially mounted telescope belonging to the Royal Society which was loaned to him by Captain John Herschel, R.E., a second telescope, a mountain barometer and a thermometer. In the course of his professional duties, Hennessey was already working in the Shivalik Hills at a site 22 km from Mussoorie. After choosing Mussoorie, he determined its altitude, latitude and longitude, and carried out observations to rate his chronometers. Mary Villa at Mussoorie, where he placed the equatorial, was appropriately named 'Venus Station'. In his report, Hennessey (1874–1875) stated: "I had seen a ring of light, but no "pear-drop" or other ligament, at internal contacts."

However, the afore-mentioned 'black drop' was clearly noticed by Colonel James Thomas Walker (1826–1896; Figure 42; Markham, 1896), who, 16 km south of Hennessey, made his observations from 'Dehra Doon', in the foothills at 2,200 feet. At that time, Walker was Superintendent of the Trigonometrical Survey of India, but he rose to become the Surveyor General, from 1878 until 1884.

The Reverend H.D. James observed the transit from Chakrata, a place in the Shivaliks at an elevation of 7,300 feet (30º 43′ N, 77º 54′ E) with a telescope of his own—made by Smith and Beck—with a 3.5-inch object-glass and a focal length of 4 feet. For timing, he used a pocket-watch that he said gained a minute in 12 hours. Chakrata lies 80 km by road west of Mussoorie. It was a cantonment of the British Indian Army, founded in 1866 by Colonel Hume and occupied in 1869.

James F. Tennant (Figure 15), by now a Colonel, arranged for observations of the transit to be made from two stations, Roorkee, where he and his team would be based, and Lahore, where he sent Captain George Strahan (1839–1911; Burrard, 1911) from the Royal Engineers (who from 1888 to 1894 would be Superintendent of the Great Trigonometrical Survey of India). Tennant set up a solar observatory by installing the photoheliograph; an equatorially mounted 6-inch Cooke refractor with a double image micrometer, sheltered in a circular observatory with a revolving roof; an alt-azimuth-mounted refractor; and a portable transit instrument and chronograph. At the first internal contact, no black-drop effect or distortion was seen, although he was expecting it, and the same occurred at egress. Captain Strahan set up his equipment in Lahore in the compound of a house. He had a 6-inch Simms refractor and two solar and sidereal chronometers. Ingress was not visible here, but with favourable weather he made observations as the transit progressed. He, too, did not see the black drop effect at egress, but noticed the planet's atmosphere. Subsequently, Tennant (1877) provided a de-

Figure 42: James Thomas Walker, who later became the Surveyor General of India (https://en.wikipedia.org/wiki/James_Walker_(Surveyor_General)#/media/File:J_T_Walker.jpg).

tailed account of the transit observations that were made under his charge, including Hennessey's observations as well. Based on these, he assigned a mean value of 8.260″ for the solar parallax. It is of interest to note that this figure is not grossly dissimilar to the best figure for the solar parallax available at that time, Encke's 1824 value of 8.5776″, which was derived from observations of the 1761 and 1769 transits (see Dick et al., 1998: 223).

Captain A.C. Bigg-Wither (1844–1913), an engineer with the Indus Valley Railway, observed the transit from his observatory at Mooltan in the Punjab with a 4-inch Cooke refractor. He did not see the black-drop effect (Bigg-Wither, 1883).

Figure 43: Father Eugene Lafont, S.J. (https://en.wikipedia.org/wiki/Eug%C3%A8ne_Lafont#/media/File:Eug%C3%A8ne_Lafont_(1837-1908).jpg).

St Xavier's College in Calcutta was founded in 1860, and made a seminal contribution to the promotion of science and technical education. A Belgian, Father Eugene Lafont, S.J. (1837–1908; Figure 43; Biswas, 1994), had joined the staff in 1865, and he had a special interest in astronomy and meteorology. In December 1874 Father Lafont went to Muddapore (Madhupur) in Bihar and joined the transit of Venus expedition organised by the Italian professional astronomer, Pietro Tacchini (1838–1905; Figure 44; Garioboldi, 2014). In the

Figure 44: Astronomer Pietro Tacchini https://upload.wikimedia.org/wikipedia/commons/9/99/Pietro_Tacchini%2C_ante_1905__Accademia_delle_Scienze_di_Torino_0110_B.jpg

process Father Lafont made the important discovery of the presence of water vapour in the atmosphere of Venus (Biswas, 1994). Following the transit, Tacchini inspired Father Lafont to set up an astrophysical observatory at the College (see Chinnici, 1995/96). This housed a 9-inch Steinheil refractor and a 7-inch Merz refractor, but little research was accomplished (Kochhar and Narliker, 1995).

One of the communications in the journal *Nature* about the transit came from Manantoddy (Mananthavady) in India. The observations in question were carried out by E.W. Pringle, who employed a small Cooke refracting telescope of 24 inches focal length and a 53× eyepiece. Pringle's account does not mention contact timings or the geographical coordinates of his site, merely stating that he was located nine miles from Manantoddy on top of an 800-feet high hill and at an elevation of 3,600 feet above mean sea level. This location is in the Wayanad Mountain Ranges, in Kerala, about 40 km from Mangalore. Pringle was an engineer with the Madras Public Works Department. We note that previously he had participated in the 12 December 1871 solar eclipse expedition at Bekul organised by the British solar physics pioneer Norman (later Sir Norman) Lockyer.

There is also information about observations made at other sites in India. According to Proctor (1882: 218),

> The whole transit was also observed by amateur astronomers at Kurrachee, Indore, and Calcutta, a fact rather showing what ought to have been done by official astronomers in England to strengthen the north Indian position, than (in all probability) adding much to the value of northern Halleyan operations.

For details of the Indian observations of the 1874 transit, see Kapoor (2014). Note that the 1882 transit was not visible from India. As with observations of the solar eclipses reviewed in Section 4.1, all Indian observations of the 1874 transit of Venus were carried out solely on astronomical grounds. The transit of Venus did not contribute to British colonial aspirations in India.

Finally, we should note that some years after the 1882 transit of Venus Simon Newcomb (1835–1909) analysed all of the known observations of the 1761, 1769, 1874 and 1882 transits and derived a value of 8.794″ for the solar parallax. This was remarkably close to the modern value of 8.794148″ that was adopted by the IAU in 1976 (see Dick et al., 1998).

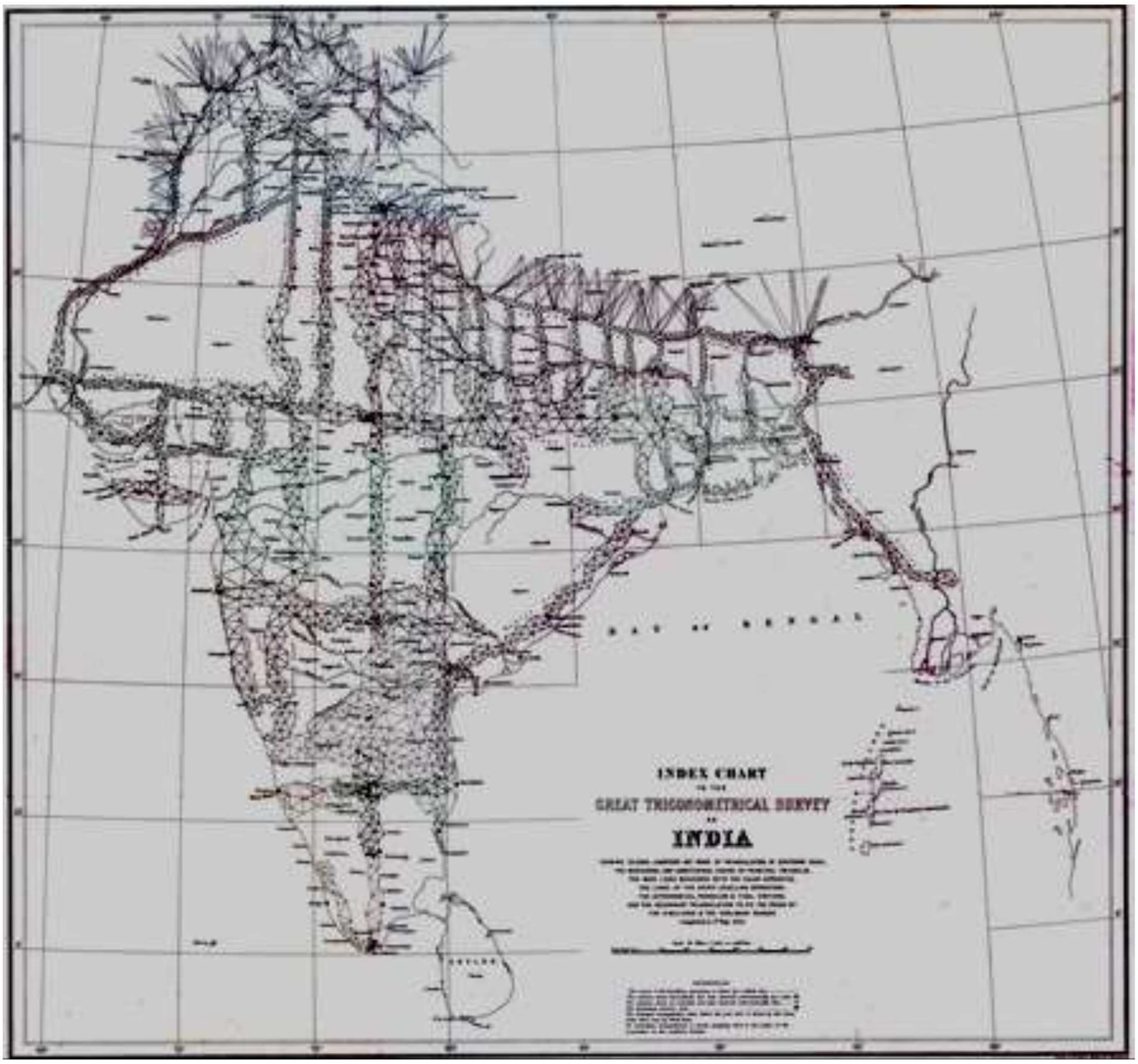

Figure 45: A map showing the various areas mapped during the Great Trigonometrical Survey of India (https://en.wikipedia.org).

5 CONCLUDING REMARKS

In the title of this paper we refer to ‘Colonial Astronomy’, which is a generic term that we use to refer to astronomical or meteorological observations carried out by astronomers in order to aid the colonial ambitions of the British in their expansion and consolidation of control in India. The late Rajesh Kochhar (1991: 77–78) pointed out that

> In the 1780s the East India Company was already a big landlord on the east coast of India. Its geographical and navigational needs now came to the fore: (i) To survey the territories it already had; (ii) to increase revenue earnings; (iii) to ensure safety of sea passages; and (iv) to learn about the geography of the country the British were increasingly getting involved with. Astronomy was thus required for navigational and geographical purposes.

Astronomical observations provided latitude and longitude, essential ingredients in creating maps for military campaigns, town planning, controlling territory, levying taxes, etc. (Edney, 1997). Meanwhile, transit observations of so-called ‘clock stars’ provided a local time service.

Madras, Colaba and Calcutta Observatories were all established by the EIC, specifically to support the Company or to conduct observations of value to the Great Trigonometrical Survey of India. Thus, the early astronomers at all three observatories were immersed in ‘colonial astronomy’, and the successive transects surveyed by staff from the Survey (see Figure 45) aided the colonial administration’s expansion of British influence in the subcontinent. Green and Deasy (1985: 20) identified three periods of exceptional expansion by the EIC, and this flurry of colonial astronomy at Madras Observatory and the Great Trigonometrical Survey coincided with the second of these, from 1786 to 1805.

The first time we witness a notable change to this predominance of colonial astronomy occurs in the 1830s, following a reorganisation of the Great Trigonometrical Survey of India in 1830 (Kochhar, 1991a). Thus, at Madras Observatory Thomas Glanville Taylor was able to further the objectives of international research astronomy by compiling what became known as the 'Madras Catalogue', a listing of more than 11,000 stars visible from Madras. Back in Mother England this won high praise from the Astronomer Royal, George Biddell Airy—in itself a notable achievement! Taylor also observed comets in order to learn more about these enigmatic visitors, and solar eclipses to help uncover secrets of the Sun. In contrast, eclipse observations by his Madras Observatory predecessors had primarily been made in order to determine the longitudes of the eclipse camps. Meanwhile, at Colaba Observatory during the 1840s Dr Buist's primary research interest was in meteors—transient objects hardly of relevance to British colonial authorities.

Another factor that encouraged pure as opposed to colonial research during the 1830s was the emergence of an international geomagnetic 'crusade' (Cawood, 1977), which was immediately embraced by astronomers at Madras and Colaba Observatories, as well as at Trivandrum Observatory (Kochhar and Orchiston, 2017: 728–732).

This emphasis on research astronomy accelerated during the 1850s and 1860s, culminating in Pogson's appointment as Director of Madras Observatory. His primary focus was on minor planets and double stars, the 1874 transit of Venus, and a succession of solar eclipses. Speaking of these eclipses, Kochhar (1991b: 127) reminds us that

> Solar physics did not come to India because the British interests needed it. It came because the British scientists required data on the Sun, which they could not collect at home, but which their sunshine-rich colony could provide.

And although the eclipses and the 1874 transit of Venus had no colonial implications, they were the catalysts that led to the establishment of new solar facilities in northern India, the Dehra Dun and Hennessey Observatories, which sought links between solar activity and terrestrial phenomena. Then in southern India, John Evershed's appointment to Kodaikanal Observatory reinforced this Indian emphasis on solar physics, and his discovery of the 'Evershed Effect' was 'icing on the research cake' so to speak.

Yet astronomical colonialism was far from dead in 1899 when Kodaikanal Observatory was founded. Notwithstanding Professor Naegamvālā's background in astrophysics and solar physics, the Astronomer Royal in England insisted that the inaugural Directorship went to a Westerner with little knowledge of or interest in solar astronomy. Had Sir Norman Lockyer's wishes prevailed and Professor Naegamvālā been appointed instead, he would have followed in the footsteps of Radhanath Sickdhar, who took charge of Calcutta Observatory in 1853, and Nanabhoy Ardeshir Framji Moos, who was appointed Director of Colaba Observatory in 1896. The precedent had been set.

6 NOTES

1. This historical relic was moved to Kodaikanal Observatory in 1900 and is still functioning (Kochhar, 1987).
2. A time ball is a time-signalling device, dropped every day at the same time, usually at 1:00 p.m. It is installed at some specific location within sight of the ships in a harbour so the officers can synchronize their chronometers. This device was first introduced at Portsmouth in 1829 (Kinns et al., 2021) and time balls, time disks, time lights, time guns and other signalling devices soon spread around the world (see Kinns, 2022). In the Indian subcontinent, at one time or another there were time balls at Karachi, Bombay, Colombo, Madras and Calcutta (Kinns, 2021), the earliest being the time ball established at Fort William, Calcutta, in 1835 (Phillimore, 1958: 114–115).
3. One year later, in 1861, this newspaper merged with two others to become *The Times of India*.
4. When he worked at the Great Trigonometrical Survey of India, prior to joining Calcutta Observatory, Sickdhar was involved in calculations that led to the identification of Peak XV in the north-eastern Himalayas as the highest mountain in the world (Lahiri, 2016). This subsequently was named Mount Everest.
5 James Francis Tennant is an interesting character, and we shall meet him again in

Sections 4.1 and 4.2. He was born in Calcutta on 10 January 1829 to Scottish parents, and after training in the EIC's Addiscombe seminary, joined the Great Trigonometrical Survey of India, serving in the Bengal Engineers (and later the Royal Engineers). Over the years he also enjoyed a number of other appointments, including serving as interim Director of Madras Observatory for one year (prior to Pogson's appointment), and as Master of the Mint, in Calcutta from 1876 to 1882. He retired from the latter post on 6 February 1882 and lived in England for the remainder of his life. There he actively pursued his astronomical interests, serving one session as President of the Royal Astronomical Society. A Fellow of both the Royal Society and the Royal Astronomical Society, he died on 6 March 1915 at the age of 86. For further information about this remarkable soldier, geodesist and astronomer see Anonymous (1915) and Hollis (1916).

6. In 1958, a decade after Indian Independence, the Observatory acquired a new solar tower telescope, which allowed an expansion of the spectroscopic research.

7 ACKNOWLEDGEMENTS

R.C. Kapoor is thankful to Dr Ilaria Cristofaro, Università della Campania Luigi Vanvitelli for helping translate the Madras Observatory Latin inscription into English; to the Survey of India, Geodetic Research Branch, Dehra Dun for permission to photograph the Hennessey Observatory and consult reference material; and to Professor Praveen B. Gawali, Indian Institute of Geomagnetism, Navi Mumbai for providing and for permission to use the figure of the Colaba Observatory.

The research presented here has made use of NASA's Astrophysics Data System, the "On-Line Solar System Data Service" of the Jet Propulsion Laboratory, CalendarHome.com and John Walker's Your Sky. Many papers and images, works of history as also those on the history of astronomy were gratefully accessed from the internet, namely, the Internet Archive, The Bibliothèque Nationale de France, Hathi Trust Digital Library, Google books, Wikimedia Commons, the Biodiversity Heritage Library at the Smithsonian Libraries and Archives in Washington, D.C. and a number of other institutions.

R.C. Kapoor is thankful to the Director, Indian Institute of Astrophysics (IIA) for facilities. This work has gratefully used many images from the Archives of the Indian Institute of Astrophysics. Thanks are due to P. Prabahar and B.S. Mohan at the Library, IIA, for help with accessing various references and to Mr. Manu Kapoor for help at the computer.

17 REFERENCES

Airy, G.B., 1854. Address by the President, G.B. Airy, Esq., F.R.S., Astronomer Royal, on presenting the Gold Medal of the Society to Mr. Charles Rumker. *Monthly Notices of the Royal Astronomical Society*, 14, 142–147.

Allan, R.J., Reason, C.J.C., Carroll, P., and Jones, P.D., 2002. A reconstruction of Madras (Chennai) mean sea-level pressure using instrumental records from the late 18th and early 19th centuries. *International Journal of Climatology*, 22, 1119–1142.

Alvi, S.M.A., 1976. *Hundred Years of Weather Service* (*1875–1975*). Poona, India Meteorological Department.

Ananthasubramanian, C.K., 1991. The Madras Observatory, 1792-1931. *Journal of the Royal Astronomical Society of Canada*, 85, 97–106.

Anonymous, 1872a. The eclipse expedition in India. *The Illustrated London News*, 10 January 1872.

Anonymous, 1872b. The eclipse of the Sun, *The Astronomical Register*, 10, 8.

Anonymous, 1878. The comets of 1618. *Nature*, 17, 247–248.

Anonymous, 1915. Obituary: Lieut.-General James Francis Tennant. *Journal of the British Astronomical Association*, 25, 240.

Anonymous, 1923. Obituary: Professor Charles Michie Smith. *Monthly Notices of the Royal Astronomical Society*, 83, 245–246.

Ansari, S.M.R., 1985. The observatories movement in India during the 17-18th centuries. *Vistas in Astronomy*, 28, 379–385.

Ansari, S.M.R., 2000. Introduction of modern Western astronomy in India during 18–19 centuries. In Sen, S.N., and Shukla, K.S. (eds.), *History of Astronomy in India*. New Delhi, Indian National Science Academy. Pp. 395–453.

Ansari, S.M.R., 2002. European astronomy in Indo-Persian writings. In Ansari, S.M.R. (ed.). *History of Oriental Astronomy*. Dordrecht, Kluwer Academic Publishers. Pp. 133–144.

Ansari, S.M.R., 2019. K.D. Naegamvālā: the founder of the first astrophysical observatory in India. In Orchiston, Sule, and Vahia, 307–324.

Astronomical Observations, Madras 1792, Indian Institute of Astrophysics Archives.

Baldini, U., 2015. Scienza, missioni, destino: Wenceslas Pantaleon Kirwitzer. In Barreto, L.F., and Wu, Z. (eds.), *Macau Past and Present*. Macau, Centro Científico e Cultural de Macau. Pp. 283–361.

Bappu, M.K.V., 2000. The Kodaikanal Observatory – a historical account. *Journal of Astrophysics and Astronomy*, 21, 103–106.

Baum, R., 2014. Maunder, Edward Waler. In Hockey et al., 1420–1421.
Bigg-Wither, A.C., 1883. Observations of the transit of Venus, 1874, December 8-9, as observed at Mooltan, Punjab, India. *Memoirs of the Royal Astronomical Society*, 47, 97–99.
Biswas, A.K., 1994. Reverend Father Eugene Lafont and the scientific activity of St. Xavier's College. *Indian Journal of History of Science*, 29, 77–88.
Buist, G., 1849. *Annals of India for the Year 1848*. Bombay, The Times Press.
Burckhalter, C., 1898. A general account of the Chabot Observatory-Pierson eclipse expedition to India. *Publications of the Astronomical Society of the Pacific*, 10, 203–212.
Burrard, S.G., 1911. Memoir: Colonel George Strahan, R.E. *The Royal Engineers Journal*, 14(3), 163–186.
Burrow, R., 1799. A proof that the Hindoos had the binomial theorem. *Asiatic Researches*, II, 487–497.
Caldecott, J., 1846. Eclipse of the Sun on Dec. 21, 1843, observed at Parratt, three miles North of the source of the Mahe River. *Memoirs of the Royal Astronomical Society*, 15, 171–178.
Campbell, W.W., 1898. A general account of the Lick Observatory-Crocker Eclipse Expedition to India. *Publications of the Astronomical Society of the Pacific*, 10, 127–140.
Campbell, W.W., 1900. Some spectrographic results obtained at the Indian eclipse by the Lick Observatory-Crocker Expedition. *Astrophysical Journal*, 11, 226–233.
Chapman, A., 1996. Scientific instruments and industrial innovation: the achievement of Jessie Ramsden. In Chapman, A. (ed.). *Astronomical Instruments and their Uses. Tycho Brahe to William Lassell*. Aldershot, Variorum. Pp. 418–430.
Chatzistergos, T., Ermolli, I., Solanki, S.K., Krivova, N.A., Banerjee, D., plus 2 further authors, 2019. Delving into the historical Ca II K archive from the Kodaikanal Observatory. The potential of the most recent digitized series. *Solar Physics*, 294(10), id.145, 24 pp.
Chinnici, I., 1995/96. An "Italian" observatory in India: the history of the Calcutta Observatory. *Studies in History of Medicine & Science*, 14(1-2), New Series, 91–115.
Christie, W.H.M., 1898. Report on the 1898 Solar Expedition to India. *Proceedings of the Royal Institution*, 15, 810–814.
Colebrooke, late Colonel R.H., 1826. Observations of an eclipse of the Moon, taken at Chouringhy, near Calcutta, in the Year 1798. *Memoirs of the Royal Astronomical Society of London*, 2, 285–286.
Copeland, R., 1898. Total solar eclipse of January 22 1898. Report on observations made at Ghoglee, Central Province. *Proceedings of the Royal Society*, 64, 21–26.
Cottam, S., and Orchiston, W., 2015. *Eclipses, Transits and Comets of the Nineteenth Century: How America's Perception of the Skies Changed.* Cham (Switzerland), Springer.
de Campigneulles, V., 1899. *Observations Taken at Dumraon, Bihar, India during the Eclipse of the 22nd Jan. 1898.* London, Longmans, Green & Co.
de Campigneulles, V., and Josson, H., 1898. *The Total Solar Eclipse on Jan. 22, 1898*. Calcutta, Thacker, Spink & Co.
Degloss, L., 1770. Observations made at Dinapoor, on the planet Venus, when passing over the Sun's disk, June 4, 1769, with three different quadrants, and a two-foot reflecting telescope ... *Philosophical Transactions of the Royal Society*, 60, 239.
de Grijs, R., 2020. A (not so) brief history of lunar distances: lunar longitude determination at sea before the chronometer. *Journal of Astronomical History and Heritage*, 23(3), 495–522.
De Souza, T.R., 1994. *Discoveries, Missionary Expansion, and Asian Cultures*. New Delhi, Concept Publishing Company.
Dewhirst, D.W., 2014. Christie, William Henry Mahony. In Hockey et al., 422–424.
Dick, S.J., Orchiston, W., and Love, T., 1998. Simon Newcomb, William Harkness and the nineteenth-century American transit of Venus expeditions. *Journal for the History of Astronomy*, 29, 221–255.
Dreyer, J.L.E., 1892. Obituary: Norman R. Pogson. *Monthly Notices of the Royal Astronomical Society, 52,* 235–238.
Espenak, F., and Meeus, J., 2006. *Five Millennium Canon of Solar Eclipses: –1999 to +3000*. Greenbelt, NASA (Technical Publication TP-2006-214141).
Field, J.H., 1926. *Report on the Administration of the Meteorological Department of the Government of India in 1925–26, and a Note on the Long-Established Observatories of Madras and Bombay.* Simla, Government of India Press.
Frost, E.B., 1913. Biographical memoir of Charles Augustus Young. *Biographical Memoirs, National Academy of Sciences*, 7, 89–114.
Gariboldi, L., 2014. Tacchini, Pietro. In Hockey et al., 2120–2123.
Gawali, P.B., Doiphode, M.G., and Nimje, R.N., 2015. Colaba–Alibag Magnetic Observatory and Nanabhoy Moos: the influence of one over the other. *History of Geo- and Space Sciences*, 6, 107–131.
Gislén, L., Launay, F., Orchiston, W., Orchiston, D.L., Débarbat, S., plus 3 further authors, 2018. Cassini's 1679 map of the Moon and French Jesuit observations of the lunar eclipse of 11 December 1685. *Journal of Astronomical History and Heritage*, 21(2 & 3), 211–225.
Goldingham, J., 1827. *Madras Observatory Papers*. Madras, Government of Madras.
Goldingham, J., 1827. On the longitude of Madras, as determined from observations of eclipses of the first and second satellites of Jupiter taken between the years 1817 and 1826. *Monthly Notices of the Astronomical Society of London*, 1(3), 13–14.
Green, W.A., and Deasy, J.P., 1985. Unifying themes in the history of British India, 1757-1857: an historiographical analysis. *Albion: A Quarterly Journal Concerned with British Studies*, 17(1), 15–45.

Grove-Hills, E.H., and Newall, H.F., 1898. Total solar eclipse of 1898 January 22. Preliminary report on the observations made at Pulgaon, India. *Proceedings of the Royal Society*, 64, 43–61.
Gubbins, D., and Herrero-Bervera, E., 2007. *Encyclopedia of Geomagnetism and Paleomagnetism*. Berlin, Springer.
Hearnshaw, J., 2014. Newall, Hugh Frank. In Hockey et al., 1561–1563.
Hennessey, J.B.N., 1874-1875. Some particulars of the transit of Venus across the Sun, December 9, 1874, observed on the Himalaya Mountains Mussoorie, at Mary Villa. Note II, with Appendix. *Proceedings of the Royal Society of London*, 23, 379–384.
Herapath, J., 1831. Observations of the comet discovered by Mr. HERAPATH, at Crawford, January 1831 – A letter from Mr HERAPATH to the President, announcing the discovery of a comet. *Memoirs of the Astronomical Society of London*, 4, 626; see, also, *Monthly Notices of the Royal Astronomical Society*, 2(1), 6–7.
Herbermann, C. (ed.), 1913a. Joseph Tiefenthaler. In *Catholic Encyclopaedia*: *Volume 14*. New York, Encyclopedia Press Inc.
Herbermann, C. (ed.), 1913b. Lorenzo Respighi. In *Catholic Encyclopedia*. *Volume 14*. New York, Encyclopedia Press Inc.
Herschel, J., 1869. Account of the solar eclipse of 1868, as seen at Jamkandi, in the Bombay Presidency. *Proceedings of the Royal Society*, 17, 104–120.
Hirst, W. The Rev, 1761-1762. An account of an observation of the transit of Venus over the Sun, on the 6th of June 1761, at Madrass … *Philosophical Transactions of the Royal Society*, 52, 396–398.
Hockey, T., Trimble, V., Williams, T.R., Bracher, K., Jarrell, R.A., Marche II, J.D., Palmeri, J, and Green, D.W.E. (eds.), 2014. *Biographical Encyclopedia of Astronomers. 2nd Edition*. New York, Springer.
Hogg, H.S., 1951. Out of old books (Le Gentil and the transits of Venus, 1761 and 1769). *Journal of the Royal Astronomical Society of Canada*, 45, 37–45; 89–92; 127–134; 173–178.
Jacob, W.S., 1843. Description of a small observatory at Poona. *Monthly Notices of the Royal Astronomical Society*, 6, 1.
Jacob, W.S., 1854. Places of Comet II. of 1854, as observed at Madras with the Lerebours Equatorial. *Monthly Notices of the Royal Astronomical Society*, 14, 246.
Jacob, W.S., 1857. Results of measurements of Saturn's satellites made at the Madras Observatory in 1856-7… *Monthly Notices of the Royal Astronomical Society*, 18, 1–3.
Janssen, J., 1873. Rapport relatif à l'observation de l'éclipse du 12 décembre 1871, addressé par M.J. Janssen au Ministre de l'Instruction Publique. *Journal Officiel de la République Française*, Jan. 16, 312–313; Jan. 19, 392–394; Jan. 20, 408–409.
Jones, N., 1967. Norman Pogson and the definition of stellar magnitude. *Astronomical Society of the Pacific Leaflet,* 469, 145–152.
Kameswara Rao, N., Vagiswari, A., and Louis, C., 1984. Father J. Richaud and early telescope observations in India. *Bulletin of the Astronomical Society of India*, 12, 81–85.
Kameswara Rao, N., Vagiswari, A., Thakur, P., and Birdie, C., 2009. C. Ragoonatha Charry and variable star astronomy. *Journal of Astronomical History and Heritage*, 12(3), 201–210.
Kameswara Rao, N; Vagiswari, A; and Birdie, C., 2014. Charles Michie Smith – founder of the Kodaikanal (Solar Physics) Observatory and beginnings of physical astronomy in India. *Current Science*, 106(3), 447–467.
Kapoor, R.C., 2006. *Reaching for the Stars*. Bangalore, Indian Institute of Astrophysics (http://prints.iiap.res.in/handle/2248/5515).
Kapoor, R.C., 2010. Telescopic discoveries of asteroids from India. *The Hawk*, 18 August (http://hdl.handle.net/2248/5232).
Kapoor, R.C., 2011. Madras Observatory and the discovery of C/1831 A1 (The Great Comet of 1831). *Journal of Astronomical History and Heritage*, 14(1), 93–102.
Kapoor, R.C., 2013. Indian astronomy and the transits of Venus 1: The early observations. *Journal of Astronomical History and Heritage*, 16(3), 269–286.
Kapoor, R.C., 2014. Indian astronomy and the transits of Venus 2: The 1874 event. *Journal of Astronomical History and Heritage*, 17(1), 113–135.
Kapoor, R.C., 2016. Nur Ud-Din Jahangir and Father Kirwitzer: the independent discovery of the Great Comets of November 1618 and the first astronomical use of the telescope in India. *Journal of Astronomical History and Heritage*, 19(3), 264–297.
Kapoor, R.C., 2018. Comet tales from India. 1: Ancient to Medieval. In Sôma, M., and Tanikawa, K. (eds.), *Proceedings of the Fifth Symposium, 22–24 March 2018, on "Historical Records of Astronomy and Modern Science."* Tokyo, National Astronomical Observatory of Japan. Pp. 14–61.
Kapoor, R.C., 2019. On observations of the Great Comet of 1807 (C/1807 R1). *Journal of Astronomical History and Heritage*, 22(1), 137–146.
Kapoor, R.C., 2021. Tales from India: The Great March Comet of 1843 (C/1843 D1). *Journal of Astronomical History and Heritage*, 24(3), 703–727.
Kapoor, R.C., 2022. Tales from India. 1: Meteor showers in classical and colonial sources. *Journal of Astronomical History and Heritage*, 25(3), 518–552.
Karbelashvili, A., 1991. Europe-India telegraph bridge via the Caucasus. *Indian Journal of History of Science*, 26, 277–281.
Kinns, R., 2020. Time signals for mariners in India, Burma and Ceylon. *Journal of Astronomical History and Heritage*, 23(3), 523–552.

Kinns, R., 2021. Visual time signals for mariners between their introduction and 1947: a new perspective. *Journal of Astronomical History and Heritage*, 25(4), 601–713.
Kinns, R., Fuller, P., and Bateman, D., 2021. Exploring the Portsmouth time balls. *Journal of Astronomical History and Heritage*, 24(3), 751–769.
Kochhar, R.K., 1985a. Madras Observatory: The beginning. *Bulletin of the Astronomical Society of India*, 13, 162–168.
Kochhar, R.K., 1985b. Madras Observatory – buildings and instruments. *Bulletin of the Astronomical Society of India*, 13, 287–302.
Kochhar, R.K., 1987. The Shelton clock at Kodaikanal. *Antiquarian Horology*, 17, 181–184.
Kochhar, R.K., 1989. Transit of Mercury 1651: The earliest telescopic observation in India. *Indian Journal of History of Science*, 24, 186–192.
Kochhar, R.K., 1991a. Astronomy in British India: Science in the service of the state. *Current Science*, 60, 124–129.
Kochhar, R.K., 1991b. The growth of modern astronomy in India, 1651-1960. *Vistas in Astronomy*, 34, 69–105.
Kochhar, R.K., and Narlikar, J.V., 1995. *Astronomy in India: A Perspective*. New Delhi, Indian National Science Academy.
Kochhar, R., 2009. Kodaikanal Observatory. In Wolfschmidt, G. (ed.), *Cultural Heritage of Astronomical Observatories: Proceedings of International ICOMOS Symposium, Hamburg*. Berlin, Hendrik Balker Verlag. Pp. 255–260.
Kochhar, R., and Orchiston, W., 2017. The development of modern astronomy and emergence of astrophysics in India. In Nakamura and Orchiston, 705–770.
Lahiri, A., 2016. Radhanath Sikdar and the final phase of measuring Peak XV. *Indian Journal of History of Science*, 51.2.1, 280–288.
Lane-Poole, S., 1885–1900. *Buist George*. In *Dictionary of National Biography, Volume 7*. (https://en.wikisource.org/wiki/Dictionary_of_National_Biography,_1885-1900/Buist,_George).
Launay, F., 1997. Autour de l'éclipse de soleil en Indie le 12 Décembre 1871. Le voyage du couple Janssen aux Neelgherries. *L'Astronomie*, 111, 111–115.
Launay, F., 2012. *The Astronomer Jules Janssen. A Globetrotter of Celestial Physics.* New York, Springer.
Launay, F., 2021. Observations of the total solar eclipse of 18 August 1868 carried out by Jules Janssen at Guntoor, India. *Journal of Astronomical History and Heritage*, 24(1), 114–124.
Le Gentil, G., 1779. *Voyage dans Les Mers de l'Inde, Fait par Ordre du Roi, à l'Occasion du Passage de Vénus, sur le Disque du Soleil, le 6 Juin 1761 & le 3 du Même Mois 1769 par M. Le Gentil, de l'Académie Royale des Sciences.* Paris, Imprimé par ordre de sa Majesté.
Lockyer, N., 1874. *Contributions to Solar Physics*. London, Macmillan.
Lockyer, N., 1898. Report on Indian Observatories and their Organisation. London, printed report dated 15 May, 44 pp. Available in the India Office Library, London, call no. IOR-L/E/7/425.
Lomb, N., 2016. Australian solar eclipse expeditions: the voyage to Cape York in 1871. *Journal of Astronomical History and Heritage*, 19, 79–95.
Louyat, C.H., 1982. *A Travers le Cosmos*. Imprimerie du Centre.
Love, H.D., 1995. *Vestiges of Old Madras 1640-1800*, New Delhi, Mittal Publications.
McConnell, A., 2007. *Jesse Ramsden (1735–1800): London's Leading Scientific Instrument Maker*. Aldershot, Ashgate.
Madras M.S. Records, 1794-1812. Indian Institute of Astrophysics Archives.
Magee, W., 1763. Minutes of the observation of the transit of Venus over the Sun, the 6th of June 1761, taken at Calcutta in Bengal … *Philosophical Transactions of the Royal Society*, 52, 582–583.
Mahias, M.-C., 2000. The black Sun of the Nilgiris: astronomy, photography and physical anthropology in South India. *Visual Anthropology*, 13, 129–148.
Majumdar, R. C. (ed.), 2007. *British Paramountcy and Indian Renaissance: The History and Culture of the Indian People*, *Volume X*. Bombay, Bharatiya Vidya Bhavan. P. 43.
Marché II, J.D., 2014. Copeland, Ralph. In Hockey et al., 460–461.
Markham, C.R., 1878. *The Indian Surveys. Second Edition*. London, W.H. Allen & Co.
Markham, C.R., 1896. Obituary. General James Thomas Walker, R.E., C.B., F.R.S. *The Geographical Journal*, 7(3), 320–323.
Maunder, E.W. (ed.), 1899. *The Indian Eclipse 1898. Report of the Expeditions Organized by the British Astronomical Association to Observe the Total Solar Eclipse of 1898, January 22*. London, Hazell, Watson and Viney.
Meadows, J., 1972. *Science and Controversy: A Biography of Sir Norman Lockyer*. Cambridge (Mass.), MIT Press.
Moos, N.A.F., 1910a. *Magnetic Observations Made at the Government Observatory, Bombay, for the Period 1846 to 1905 and their Discussion, Part I: Magnetic Data and Instruments*. Bombay, Government Central Press.
Moos, N.A.F., 1910b. *Magnetic Observations Made at the Government Observatory, Bombay, for the Period 1846 to 1905 and their Discussion, Part II: The Phenomenon and its Description*. Bombay, Government Central Press.
Mukherjee, S.K. (ed.), 1985. History of Astronomy in India. *Indian Journal of History of Science*, 20.
Mukhopadhyay, U., 2014. Radhanath Sikdar first scientist of Modern India. *Science and Culture*, 80(May-June), 142–146.

Mumpuni, E.S., Orchiston, W., and Steinicke, W., 2017. J.A.C. Oudemans' observations of the 18 August 1868 and 12 December 1871 total solar eclipses from the Dutch East Indies. In Nakamura and Orchiston, 357–373.
Naegamvala, K.D., 1898. Photograph of the spectrum of the "Flash" at the solar eclipse of 21 January, 1898. *Astrophysical Journal*, 8, 120–121.
Naegamvala, K.D., 1902. *Report on the Total Solar Eclipse of January 21–22, 1898, as Observed at Jeur in Western India*. Bombay, Government Printer.
Nakamura, T., and Orchiston, W. (eds.), 2017. *The Emergence of Astrophysics in Asia: Opening a New Window on the Universe*. Cham (Switzerland), Springer.
Nath, B.B., 2013. *The Story of Helium and the Birth of Astrophysics*. New York, Springer.
Nath, B.B., and Orchiston, W., 2021. Norman Robert Pogson and observations of the total solar eclipse of 1868 from Masulipatam, India. *Journal of Astronomical History and Heritage*, 24(3), 629–651.
Orchiston, W., 2005. James Cook's 1769 transit of Venus expedition to Tahiti. In Kurtz, D.W. (ed.). *Transits of Venus: New Views of the Solar System and Galaxy*. Cambridge, Cambridge University Press. Pp. 52–66.
Orchiston, W., Orchiston, D.L., George, M., and Soonthornthum, B., 2016. Exploring the first scientific observations of lunar eclipses made in Siam. *Journal of Astronomical History and Heritage*, 19(1), 25–45.
Orchiston, W., 2017. Cook, Green, Maskelyne and the 1769 transit of Venus: the legacy of the Tahitian observations. *Journal of Astronomical History and Heritage*, 20(1), 35–68.
Orchiston, W., Lee, E.-H., and Ahn, Y.-S., 2017. British observations of the 18 August 1868 total solar eclipse from Guntoor, India. In Nakamura and Orchiston, 771–793.
Orchiston, W., and Orchiston, D.L., 2017. King Rama IV and French observations of the total solar eclipse of 18 August 1868 from Wah-koa, Siam. In Nakamura and Orchiston, 291–317.
Orchiston, W., and Pearson, J., 2017. American observations of the 22 January 1898 total solar eclipse from Jeur, India. In Nakamura and Orchiston, 795–814.
Orchiston, W., Orchiston, D.L., George, M., Soonthornthum, B., Gislén, L., plus 2 further authors, 2019. The role of eclipses and European observers in the development of 'modern astronomy' in Thailand. In Orchiston, Sule and Vahia, 173–216.
Orchiston, W., Sule, A., and Vahia, M. (eds.), 2019. *The Growth and Development of Astronomy and Astrophysics in India and the Asia-Pacific Region. ICOA-9, Pune, India,*15-18 November 2016. New Delhi, Hindustan Book Agency and Springer Nature.
Orchiston, W., Dumon, P., Gislen, L., Orchiston, D.L., George, M., plus 4 further authors, 2021a. Father Antoine Thomas and the birth of 'modern astronomy' in Thailand. In Orchiston and Vahia, 225–252.
Orchiston, W., Mumpuni, E.S., and Steinicke, W., 2021b. J.A.C. Oudemans and nineteenth century astronomy in the Dutch East Indies. In Orchiston and Vahia, 285–315.
Orchiston, W., and Orchiston, D.L., 2021. King Rama IV, Sir Harry Ord and the total solar eclipse of 18 August 1868: power, politics and astronomy. *Journal of Astronomical History and Heritage*, 24(2), 389–404.
Orchiston, W., Orchiston, D.L., Gislén, L., George, M., Soonthornthum, B., plus 3 further authors, 2021c. Show-casing seventeenth-century Jesuit astronomy in Asia: the lead up to the first scientific observations of a solar eclipse made in Siam. *Journal of Astronomical History and Heritage*, 24(2), 498–520.
Orchiston, W., and Vahia, M. (eds.), 2021. *Exploring the History of Southeast Asian Astronomy: A Review of Current Projects and Future Prospects and Possibilities*. Cham (Switzerland), Springer.
Orchiston, W., Orchiston, D.L., George, M., Soonthornthum, B., and Komonjinda, S., 2022. Seventeenth century Jesuit astronomical activities in Siam. In Shi, Y., and Chu, L. (eds.), *Astronomical Heritages in Asia-Pacific Areas: Proceedings of the Eighth International Conference on Oriental Astronomy*. Hefei, University of Science and Technology of China. Pp. 89–112.
Orlebar, A.B., 1846. *Observations Made at the Magnetical and Meteorological Observatory, Bombay from April to December 1845*. Bombay, American Mission Press.
Pang, A.S.-K., 2002. *Empire of the Sun. Victorian Solar Eclipse Expeditions*. Stanford, Stanford University Press.
Pasachoff, J.M., and Sheehan, W., 2012. Lomonosov, the discovery of Venus's atmosphere, and eighteenth century transits of Venus. *Journal of Astronomical History and Heritage*, 15(1), 3–14.
Pearson, J.C., and Orchiston, W., 2008. The 40-foot solar eclipse camera of the Lick Observatory. *Journal of Astronomical History and Heritage*, 11, 25–37.
Pearson, J.C., Orchiston, W., and Malville, J.M., 2011. Some highlights of the Lick Observatory solar eclipse expeditions. In Orchiston, W., Nakamura, T., and Strom, R. (eds.), *Highlighting the History of Astronomy in the Asia-Pacific Region*. New York, Springer. Pp. 243–337.
Phillimore, R.H., 1945. *Historical Records of the Survey of India*, *Volume I*. Dehra Dun, Survey of India.
Phillimore, R.H., 1954. *Historical Records of the Survey of India*, *Volume II.* Dehra Dun, Survey of India.
Phillimore, R.H., 1955. *Historical Records of the Survey of India*, *Volume III.* Dehra Dun, Survey of India.
Phillimore, R.H., 1958. *Historical Records of the Survey of India*, *Volume IV*. Dehra Dun, Survey of India.
Phillimore, R.H., 1968. *Historical Records of the Survey of India*, *Volume V*. Dehra Dun, Survey of India.
Plummer, H.C., 1931. Professor H.H. Turner. *Monthly Notices of the Royal Astronomical Society*, 91, 321–334.
Pogson, N.R., 1861. *Proceedings of Madras Government Public Department*. Madras, Madras Government.
Pogson, N.R., 1867. Reports upon the Madras Observatory for the Official Year 1865, May Ist, to 1866 April 30th. *Monthly Notices of the Royal Astronomical Society*, 27, 122–126.
Pogson, N.R., 1868. *Administration Report of the Government Observatory for the year 1868*. Madras, Madras Government.

Pogson, N.R., 1869. *Report of the Government Astronomer Upon the Proceedings of the Observatory, in Connexion with the Total Eclipse of the Sun on August 18th, 1868, as Observed at Masulipatam, Vunpurthy, Madras and Others Stations in Southern India*. Madras, Madras Observatory.

Pogson, N.R., 1872. Observations made during the eclipse of June 6, 1872. *Monthly Notices of the Royal Astronomical Society*, 32(9), 330–331.

Pogson, N.R., 1874. *Administrative Report of the Madras Observatory for the Year 1874*. Madras, Government Press.

Pogson, N.R., 1875. Transit of Venus. *The Astronomical Register*, 13, 116.

Pogson, N.R., 1884. *Magnetic Observations Made at The Honourable The East India Company's Observatory at Madras under the Superintendence of W.S. Jacob, in the years 1851–1855*. Madras, Madras Observatory.

Popular Astronomy, 2 (1913).

Proceedings Asiatic Society of Bengal 1873. January to December 1872. Calcutta, Baptist Mission Press (1873).

Proceedings Asiatic Society of Bengal 1875. January to December 1874. Calcutta, Baptist Mission Press (1875).

Proctor, R.A., 1882. *Transits of Venus*. London, Longmans, Green, and Co.

Ranyard, A.C., 1879. The solar corona. *Memoirs of the Royal Astronomical Society*, 41, 1–791.

Ragoonathachary, C., 1871. On the total eclipse of the Sun, on December the 11th, 1871, 12 visible in the Madras Presidency. *Monthly Notices of the Royal Astronomical Society*, 31, 137–146.

Reddy, V., Snedegar, K., and Balasubramanian, R.K., 2007. Scaling the magnitude: the rise and fall of N.R. Pogson. *Journal of the British Astronomical Association*, 117, 237–245.

Report of the Committee of Solar Physics. London, H.M. Stationery Office (1882).

Rose, A, 1770. Extract of two letters from the late Capt. Alexander Rose of the 52d Regiment to Dr Murdoch, F.R.S. *Philosophical Transactions of the Royal Society*, 60, 444–450.

Rothschild, R.F., 2009. *Two Brides for Apollo*: *The Life of Samuel Williams (1743–1817).* New York, iUniverse.

Samant, H., and Samant, A., 2016. The Ghadiyal Godi timeball – a maritime legacy of Bombay Port. *The Bombay Explorer*, 55, 2–11.

Sandeman, H.D., 1868. *Selections from Calcutta Gazettes of the Years 1806 to 1815 Inclusive. Volume IV.* Calcutta, Office of Superintendent Government Printing.

Sangwan, S., 2000. Science and its public in British India problematic of diffusion and social appropriation. In Sehgal, N.K., Sangwan, S., and Mahanti, S. (eds.), *Uncharted Terrains.* New Delhi, Vigyan Prasar. Pp. 13–53.

Schaffer, S., 2012. The Bombay case: astronomers, instrument makers and the East India Company. *Journal for the History of Astronomy*, 43, 151–180.

Schielicke, R., and Wittmann, A.D., 2005. On the Berkowski daguerreotype (Königsberg, 1851 July 28): the first correctly-exposed photograph of the solar corona. *Acta Historica Astronomiae*, 25, 128–147.

Sen, J., 2014. *Astronomy in India, 1784–1876*. London, Pickering and Chatto.

Sen, S.N., 1982. Tiefenthaler on latitudes and longitudes in India – an eighteenth century study of geographical coordinates. *Indian Journal of History of Science*, 17(1), 1–17.

Sen, S.N., 1989. Madras meridian circle observations of fixed stars during 1862 to 1887. *Indian Journal of History of Science*, 24, 257–283.

Sen, S.N., and Shukla, KS. (editors), 2000. *History of Astronomy in India*. New Delhi, Indian National Science Academy.

Sharma, M.L., 1982. Jagannath Samrat's outstanding contribution to Indian astronomy in eighteenth century AD. *Indian Journal of History of Science*, 17(2), 244–251.

Sheehan, W., and Westfall, J., 2004. *The Transits of Venus*. Amherst, Prometheus Books.

Shiltsev, V., 2014. The 1761 discovery of Venus' atmosphere: Lomonosov and others. *Journal of Astronomical History and Heritage*, 17(1), 85–112.

Shylaja, B.S., 2012. *Chintamani Ragoonathachari and Contemporary Indian Astronomy*. Bangalore, Navakarnataka Publishers.

Soonthornthum, B., and Orchiston, W., 2021. King Rama IV: astronomer and 'The Father of Thai Science'. In Orchiston and Vahia, 253–284.

Sthanapati, J., 2010. Geomagnetic studies in the 19th century British India. *Propagation*, 1, 77–80.

Stratton, F.J.M., 1957. John Evershed 1864-1956. *Biographical Memoirs of Fellows of the Royal Society*, 3, 40–51.

Taylor, T.G., 1832. Observations of the comet of January 1831. In *Results of Astronomical Observations Made at The Honourable The East India Company's Observatory at Madras*. *Volume I. For the Year 1831*. Madras, Madras Observatory. Pp. 95–100.

Taylor, T.G. 1835 *Result of Astronomical Observations Made at the Honorable, the East India Company's Observatory at Madras. Volume III. For the Years 1833 and 1834*. Madras, Madras Observatory.

Taylor, T.G., 1837. Observations of the magnetic dip and intensity at Madras. *The Journal of The Asiatic Society of Bengal*, 6, 374–377.

Taylor, T.G., 1838. *Results of Astronomical Observations Made at The Honourable The East India Company's Observatory at Madras by T G Taylor. Volume IV for the years 1836 and 1837*. Madras, Madras Observatory.

Taylor, T.G., 1844. *A General Catalogue of the Principal Fixed Stars from Observations Made at The Honorable The East India Company's Observatory at Madras in the Years 1830-1843*. *Volume 6*. Madras, Madras Observatory.

Tennant, J.F., 1869. Report on the total eclipse of the Sun, August 17–18, 1868 … *Memoirs of the Royal Astronomical Society*, 37, 1–55.

Tennant, J.F., 1872. Report on the observations made by the Government of India on the total eclipse of the Sun on Dec. 11-12, 1871. *Monthly Notices of the Royal Astronomical Society*, 32, 253–254.

Tennant, J.F., 1875. Report of observations of the total eclipse of the Sun on December 11-12, 1871, made by order of the Government of India, at Dodabetta, near Ootacamund. *Memoirs of the Royal Astronomical Society*, 42, 1–33.

Tennant, J.F., 1877. *Report on the Preparations for, and Observations of the Transit of Venus, as seen at Roorkee and Lahore, on December 8, 1874.* Calcutta, Office of the Superintendent of Government Printing.

Terao, H., and Hirayama, S., 1910. Report on the Total Solar Eclipse of the Sun observed at Jeur, in Western India on January 22, 1898. *Annales de l'Observatoire Astronomique de Tokyo, III*(1).

The Royal Society, 1846. Record. EC - Certificates of election and candidature for Fellowship of the Royal Society. 1846 – Certificates of election 1846. Buist George, EC/1846/07 (https://catalogues.royalsociety.org/CalmView/Record.aspx?src=CalmView.Catalog&id=EC%2f1846%2f07; accessed 17 February 2021).

Udias, A., 2003. *Searching the Heavens and the Earth: The History of Jesuit Observatories*. Dordrecht, Kluwer.

van Gent, R.H., 2004. *Transit of Venus Bibliography*. Institute for History and Foundations of Mathematics and the Natural Sciences, Utrecht University (https://webspace.science.uu.nl/~gent0113/venus/venustransitbib.htm).

Venkateswaran, T.V., 2021. Ragoonatha Charry and the observations of the total solar eclipse of 1868 from Vanpurthy (Wanparthy), India. *Journal of Astronomical History and Heritage*, 24(2), 363–388.

Vsekhvyatskii, S.K. 1964. *Physical Characteristics of Comets*. Jerusalem, Israel Program for Scientific Translations.

Winter, G.K., 1869. Observations of the total eclipse of August 18th, 1868, made at Masulipatam. Madras, Madras Observatory.

Woolf, H, 1959. *The Transits of Venus: A Study in Eighteenth Century Science*. Princeton, Princeton University Press.

Worster, W.K., and Jacob, W.S., 1854. *Astronomical Observations Made at The Honorable The East India Company's Observatory at Madras for the Years 1848-1852. Volume 8.* Madras, Madras Observatory.

Wright, W.H., 1949. William Wallace Campbell. *Biographical Memoirs, National Academy of Sciences*, 25, 35–74.

Professor Ramesh Kapoor began his career in 1971 at the Uttar Pradesh State Observatory (now Aryabhatta Research Institute of Observational Sciences, ARIES) at Nainital in observational astronomy. His main interest was flare stars. From March 1974 until September 2010 he was with the Indian Institute of Astrophysics (IIA), Bangalore, where he worked on various topics in relativistic astrophysics—observational aspects of black holes, white holes, quasars and pulsars, etc.

He has participated as observer and organizer in a few solar eclipse expeditions of the IIA, and also went out to observe a few on his own. He has published in peer-reviewed journals and presented papers at national and international conferences.

Ramesh's current interest is the history of astronomy in the Indian region, and he has published a succession of papers in this journal—mainly about eclipses, comets and meteors observed from India. He has all along been active in popularizing astronomy. He has published also on Indian Systems of Medicine.

He has been a member of the International Astronomical Union since 1985, and is a Life Member of the Astronomical Society of India (since 1973) and an Associate of the National Institute of Advanced Studies (NIAS, IISc) since 2002. He has also been an Associate of COSPAR Commission E since 2005.

Professor Wayne Orchiston was born in Auckland (New Zealand) in 1943, and has BA Honours and PhD degrees from the University of Sydney. Currently, he is employed by the University of Science and Technology of China in Hefei as a Co-editor of the *Journal of Astronomical History and Heritage*. He is also an Adjunct Professor of Astronomy in the Centre for Astrophysics at the University of Southern Queensland (USQ) in Toowoomba, Australia. Formerly, Wayne worked at the National Astronomical Research Institute of Thailand (Chiang Mai), James Cook University (JCU, Townsville, Australia), the Australia Telescope National Facility (Sydney) and Carter Observatory (Wellington, New Zealand). Over the past two decades he has supervised >35 Master of Astronomy and PhD history of astronomy research projects through JCU, USQ and Western Sydney University.

Wayne has wide-ranging research interests but has mainly published on historic transits of Venus; historic solar eclipses; historic telescopes and observatories; the emergence of astrophysics; the history of cometary and meteor astronomy; the astronomy of James Cook's three voyages to the Pacific; amateur astronomy and the amateur–professional interface; the history of meteoritics; the history of radio astronomy in Australia, France, India, Japan, New Zealand and the USA; and Indian, Southeast Asian and Māori ethnoastronomy. Wayne has published a number of papers on the history of optical astronomy and radio astronomy in India.

Recent books by Wayne include *Exploring the History of New Zealand Astronomy …* (2016, Springer); *John Tebbutt: Rebuilding and Strengthening the Foundations of Australian Astronomy* (2017, Springer); *The Emergence of Astrophysics in Asia …* (2017, Springer, co-edited by Tsuko Nakamura); *Exploring the History of Southeast Asian Astronomy …* (2021, Springer, co-edited by Mayank Vahia) and *Golden Years of Australian Radio Astronomy: An Illustrated History* (2021, Springer, co-authored by Peter Robertson and Woody Sullivan). Since 2005 he has also edited or co-edited a succession of conference proceedings.

Wayne has also been a member of the IAU since 1985, and he is the current Immediate Past President of Commission C3 (History of Astronomy). He is the Founding Chair of the History & Heritage Working Group of the SE Asian Astronomy Network, and in November 2022 he and Glen Rowe formed the Historical Section of the Royal Astronomical Society of New Zealand. In 1998 Wayne co-founded the *Journal of Astronomical History and Heritage,* and was the Managing Editor until 31 July 2022. In 2013 the IAU named minor planet 48471 'Orchiston', and in 2019 he and Dr Stella Cottam were co-recipients of the American Astronomical Society's Donald Osterbrock Book Prize for their 2015 Springer book, *Eclipses, Transits and Comets of the Nineteenth Century: How America's Perception of the Skies Changed*.

Wayne and his wife Darunee Lingling Orchiston (who doubles as his part-time Research Assistant) live in a quiet village about one hour by road from Chiang Mai in far northern Thailand.