CHASING MERCURY: TRANSIT TALES FROM INDIA

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Abstract: Planets passing across the disk of the Sun are among the most uncommon and fascinating phenomena in the Solar System. From the Earth, the transits of only Mercury and Venus can be seen. Early on, the transits of Venus were important for precisely determining the scale of the Solar System whereas the transits of Mercury were used to accurately ascertain its orbit and variations in the size of the Sun. This paper presents observations of transits of Mercury made in India from 1651 until 1927 (the last one before Independence in 1947). The observers were East India Company engineers and British officials, European missionaries and geographers and professional and amateur astronomers. In our quest, we stumbled across brief references to the transits of 1753 and 1756 observed by the Jesuit Gaston-Laurent Coeur-doux in Puducherry, and of 1815 by John Hodgson of the East India Company's Bengal Infantry in Dalmau. We also present the unpublished observations of the transit of 1861 made by Norman Pogson at Madras Observatory. Finally, we report on photographs of the 8 May 1924 and 10 November 1927 transits taken at Kodaikanal Observatory as part of their on-going solar physics research.

Keywords: transits of Mercury; Indian observations; transit of 1651; transit of 1753; transit of 1756; transit of 1815; transit of 1861; transit of 1924; transit of 1927.

1 INTRODUCTION

Transits of Mercury and Venus have been observed since 1631 and 1639 CE respectively. Expeditions were mounted to the far 'corners' of the world to view historic transits of Venus which allowed astronomers to determine the solar parallax—and hence the astronomical unit (*au*), the Earth–Sun distance—with unprecedented accuracy, and gauge the scale of the Solar System (Halley, 1716; Kurtz, 2004; Verdun, 2004). These transits enabled astronomers to test and improve the accuracy of the ephemerides, but they also demonstrated an anomaly in the planetary apsidal precession.

From the contact timings of the transits over the period 1661–1848, Le Verrier (1859) first determined Mercury's perihelion advance caused by known perturbation effects. This revealed an unexplained anomaly of 38″.3/century over and above the Newtonian value of 532″.805/century. The anomaly, later valued at 42″.98/century, was explained by Albert Einstein applying the Theory of General Relativity. The latest total observed value is 575″.31/century, obtained by Park et al. (2017) from the ranging measurements acquired by the MESSENGER spacecraft (ranging accuracy ~1*m*). When Simon Newcomb (1896: 1237) compared the contact timings of the November transits observed over 1677–1894 with the calculated ones, he found that the Earth's rotation was not perfectly uniform (c.f. Newcomb, 1882).

An accurate determination of the solar radius has been of paramount importance in astronomy. The transits of Mercury and Venus have helped in this matter too. Analyses of data from the transits of Mercury of 1723 through to 1973 gave a striking result—a decrease in the solar radius of 0″.14 ± 0″.08 (Morrison and Ward, 1975; Parkinson et al., 1980). For the first time, by timing the transits of 7 May 2003 and 8 November 2006 with the Michelson Doppler Imager (MDI) aboard the Solar and Heliospheric Observatory (SOHO), Emilio et al. (2012: 141) arrived at the figure 960″.12 ± 0″.09 (i.e. 696,342 ± 65 km) for the solar radius, with an uncertainty of only 65 km. They also found that this value was consistent between the transits. The technique is unprecedented and largely devoid of optical distortions. Such observations are most valuable for measuring its long-term variation. During the 2012 transit of Venus, the measurements by the PICARD spacecraft gave a photospheric solar radius of 696,156 ± 145 km (1σ) (Meftah et al., 2014).

On 4 June 2014, a planetary transit was seen for the first time from another planet. The MAST camera on NASA's Mars Rover Curiosity watched Mercury transitting the Sun. From Mars, one can also see the Earth transit the Sun. Since the space telescope Kepler and the Transiting Exoplanet Survey Satellite (TESS) were launched in 2009 and 2018 respectively, transit events have been fruitfully used to detect exoplanets orbiting distant stars. According to the *Encyclopaedia of Exoplanetary Systems*, as of 29 September 2024 there were 4466 planets detected by their primary transits (https://exoplanet.eu/home/).

This paper is about the transits of Mercury observed from India between 1651 and 1927

* It is with great sadness that we report that Professor Ramesh Kapoor died suddenly on 21 August 2025 after a brief illness. This paper is one of a number that he submitted to *JAHH* shortly before his death. For information about Ramesh's life and research see Venkateswaran and Orchiston (2025).

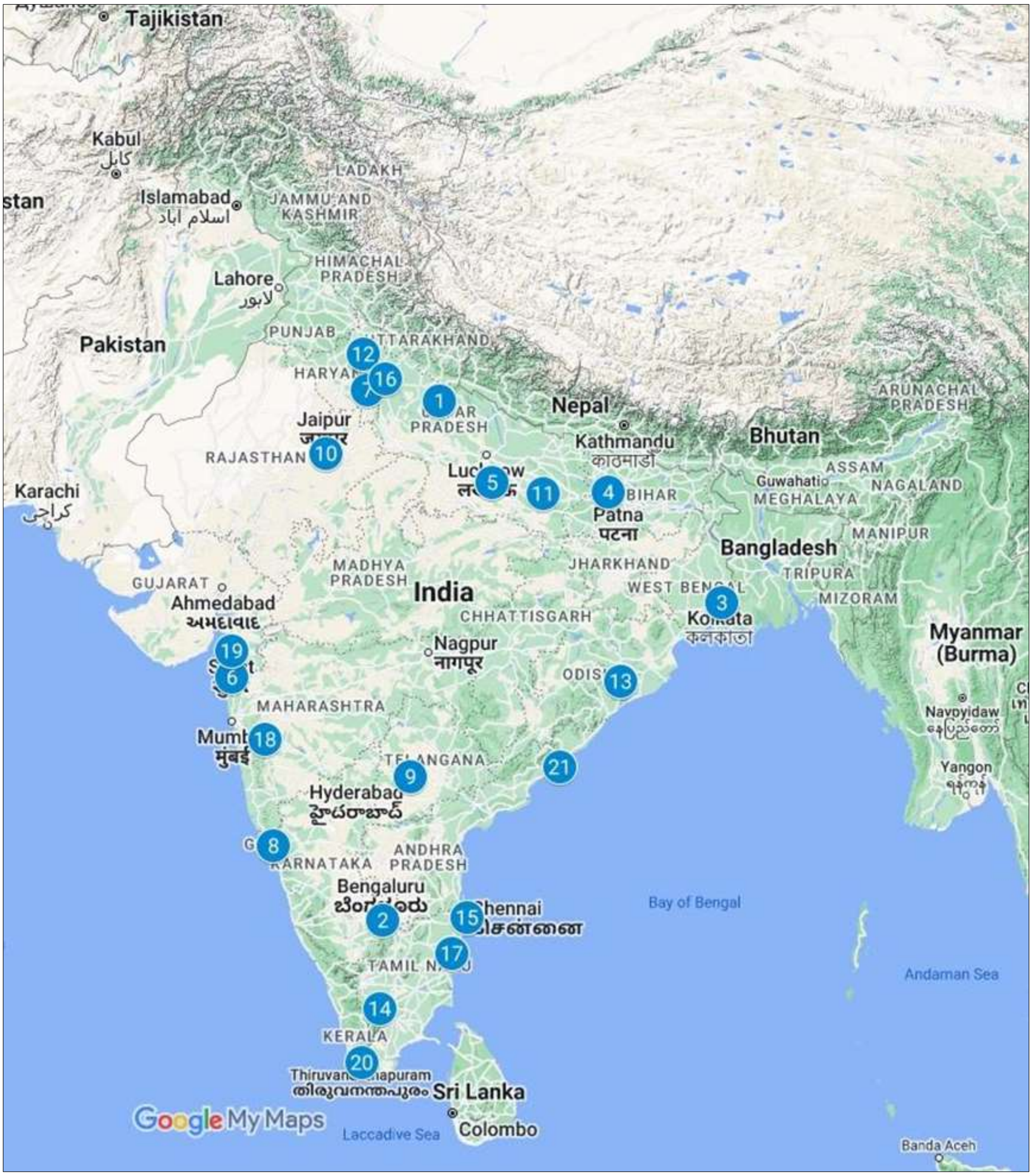


Figure 1: The locations in India mentioned in this paper: 1. Barelly, 2. Bangalore, 3. Calcutta, 4. Chupra, 5. Dalmow, 6. Daman, 7. Delhi, 8. Goa, 9. Hyderabad, 10. Jaipur, 11. Jionpoor, 12. Kurnal, 13. Khandapada, 14. Kodaikanal, 15. Madras, 16. Meerut, 17. Pondicherry, 18. Poona, 19. Surat, 20. Trivandrum, 21. Vizagapatam (Google Maps; map modifications: R.C. Kapoor).

the last one before Independence in 1947). Figure 1 shows the Indian locations mentioned in this paper.

Please note that in order to retain the historical flavour, we decided to use the old names and spellings as found in the original accounts. Note, also, that some observers gave transit times according to the astronomical day, which began at noon, 12 hours after the start of the civil day.

2 TRANSITS OF MERCURY

Basic information about Mercury is provided by Williams (2024). The sidereal period of Mercury is 87.969 days. In its course, Mercury passes in between the Earth and the Sun. A line-up takes place every 115.88 days, the synodic period—the time between two successive inferior or superior conjunctions. As the orbit of Mercury is inclined 7°.004 to the ecliptic, it crosses the plane of the ecliptic at two points, the nodes.

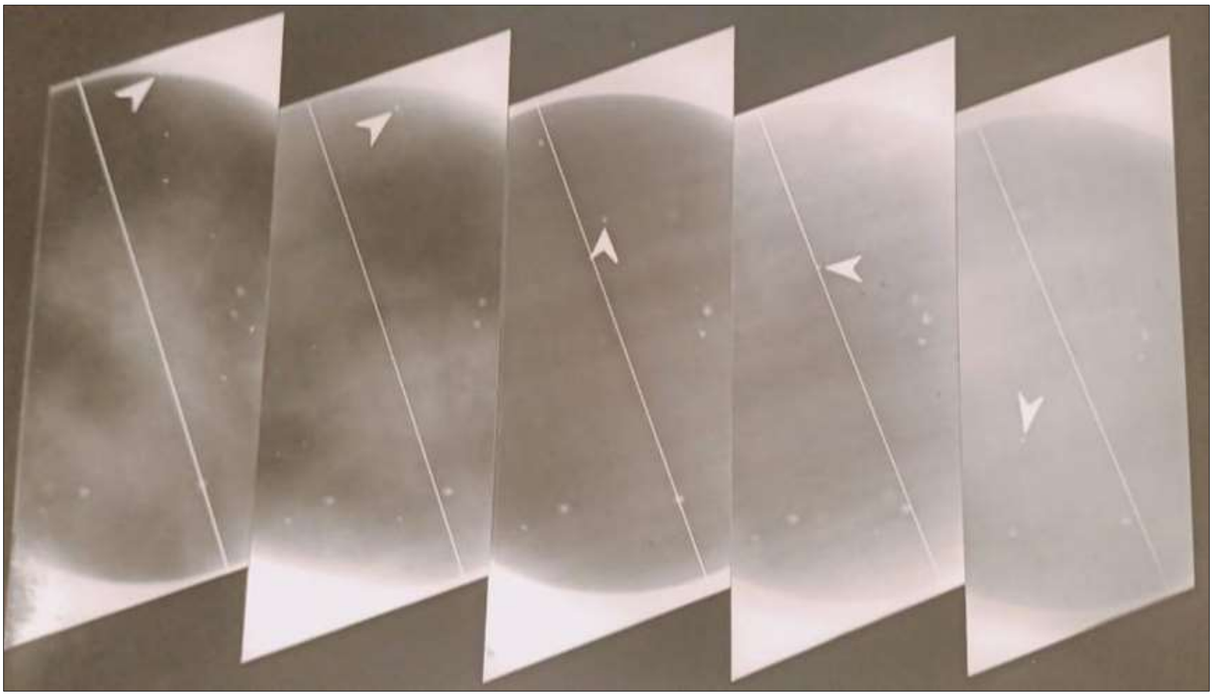


Figure 2: The transit Mercury in progress on 9 May 1970, shown on composite negatives from Kodaikanal Solar Observatory (courtesy: Indian Institute of Astrophysics Archives, Bengaluru).

Whenever a line-up occurs at or very near a node, a transit will occur (Figure 2).

A transit is essentially an annular eclipse, difficult to notice since the planets are much smaller than the Sun in angular dimensions. The planet Venus is not only bigger than Mercury (mean radius 6051.8 km against 2439.4 km), it is also relatively closer to the Earth at the time of its inferior conjunction. Even then, it subtends an angle of about 1′ only (approximately 1⁄31 of the Sun) and while in transit, the planet appears as a small round black dot against the extremely bright disk of the Sun. Until its relatively rapid motion is noticed, it can easily be mistaken for a small isolated sunspot. Incidentally, this is also the limit of detection by the normal human eye. There are claims that transits of Venus have been seen with the naked eye (Kapoor, 2013a), but a transit of Mercury cannot be seen in this way.

In Meeus (2015), Espenak (2016) and https://www.projectpluto.com/transits.htm there are tables of various planetary phenomena and the transits covering a long period. Looking up the tables, we find that transits of Mercury occur in either May or November. The longitude of the Ascending Node lies at 48°.33167, or 18°.33167 of Taurus and the Descending Node at 18°.33167 of Scorpio (Williams, 2024). Compare it with the value determined by de Lalande for the year 1750: 15° 20′ 43″ in Taurus (Vince, 1814: 155) and that it varies by 1° 12′ 10″ every century (Vince, 1814: 161). The Sun appears to pass these points twice a year, on 7 May and 9 November. Transits happen within three days of the former and within five days of the latter date.

Since the orbital eccentricity is large (e = 0.2056), there is also a 20% change in the angular diameter of Mercury between the transits. In the May transits, Mercury is closer to the Earth and measures ~12″. In the November transits, it is closer to the Sun and the value is smaller, ~10″. Then it also traverses the disc faster. As it is also closer to the ecliptic plane, the November transits are twice as frequent as the May transits.

There are 13–14 transits of Mercury in a century; there are 14 in the present century. As the orbit of Venus (mean value 0.7233 au; 1 au = 149,597,870,700*m*; IAU, 2012) is much bigger than that of Mercury (mean value 0.3869 au), a transit of Venus is that much rarer; they number about 12 in a millennium. The node months of Venus are December (node in Gemini) and June (node in Sagittarius). Since the invention of the telescope, there have been only eight transits of Venus. The transits of 1761, 1769, 1874, 2004 and 2012 were all observed from India (Kapoor, 2012, 2013a, 2013b, 2014).

3 *MERCURIUS IN SOLE VISUS*

The first pointers to the possibility of a planet transiting the Sun are found in the Book I, Part A of *Planetary Hypotheses* by Claudius Ptolemy (ca. 100–ca. 175 CE). In his planetary order, namely, Moon, Mercury, Venus, Sun, Mars, Jupiter and Saturn, the spheres of Mercury and Venus lie below the Sun. Ptolemy held that if a transit had never been observed, it does not mean that it never occurred. The planets were either too small to be perceptible against a large body with so much light, or the events were too rare.

3.1 Kepler and His *Phænomenon Singulare seu Mercurius in Sole*

A millennium and a half later, the scene shifted to Prague where in late May 1607 Johannes Kepler (1571–1630; Figure 3) had been observing Mercury. The ephemerides alluded to a critical conjunction with the Sun coming up. Kepler arranged to watch it with a *camera obscura*, as depicted in his book *Phænomenon Singulare seu Mercurius in Sole* (*A Unique Phenomenon or Mercury in the Sun*; Keppleri, 1609: 33). The very idea that one might be able to see a small, finite-sized body traverse the face of the bright Sun this way was unprecedented, since the astronomers had no idea of the physical size of planets and whether they differed from the size assigned them through the ages. They did nurture a vague idea of the size of the Solar System though.

On 28 May 1607 (Gregorian Calendar), Kepler noticed a *maculum* on the solar image. He thought the spot was the planet Mercury on the Sun, but years later he conceded that what he had seen was possibly a big sunspot. This is admitted in *Joannis Kepleri Astronomi Opera Omnia* (*Kepler's Collected Works on Astronomy*, edited by Dr. Ch. Frisch in eight volumes, 1858–1891) and we read about it in Volume II (Frisch, 1859: 775):

> Kepler deals in a few pages in this book on the observation of a solar spot, which he mistakenly believed to be Mercury appearing in the disk of the Sun. Acknowledging this error after reading the books and letters of John Fabricius and Scheiner on solar spots, he frankly admitted it, and occasionally returned to this error apologizing in his later books and private letters.[1]

There indeed was a transit of Mercury but in 1605 on 1 November, and it happened when it was nighttime in Europe. Kepler was hoping in 1607 to observe it. That was only a while before he would introduce a radical change in mathematical astronomy through the first two laws of planetary motion formulated in his *Astronomia Nova* (1609); the third planetary law was published in 1619. Moving away from the concept of orbs, or the rotating solid celestial spheres carrying the planets along, Kepler introduced the concept of elliptical orbits—paths that the planets take as they move through space, with the Sun at one of the foci.

Kepler's *Tabulæ Rudolphinæ* came out in 1627 (Figure 4) which enabled one to accurately compute solar and planetary positions in the sky for any date. The *Tabulæ*, named for Rudolf II (1552–1612) of the Holy Roman Empire, adopted the heliocentric worldview, together with the idea of elliptical planetary orbits. It had tables of logarithms, geographical positions of many cities, catalogue of 1005 stars and the planetary tables. Based on the *Tabuæ*, Kepler computed ephemerides for 1629–1639. That led him to foresee a conjunction of Mercury with the Sun on 7 November 1631. He did not live to witness it but Pierre Gassendi took note of it and was able to make successful observations of it from Paris (Section 3.2).

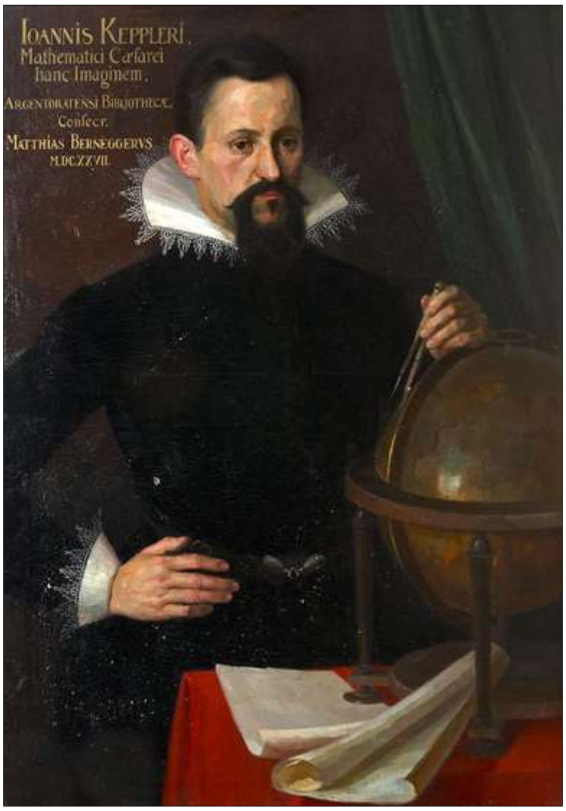


Figure 3: A 1910 portrait of Johannes Kepler, based on a 1620 original (Wikimedia Commons).

The first of the transits of Venus as predicted by Johannes Kepler happened on 7 December 1631 CE, but the next one, according to him, was not to be until 1761 (Whatton, 1859: 17). Looking through the *Tabulæ Rudolphinæ*, the British astronomer Jeremiah Horrox (also Horrocks; 1619–1641 CE; Applebaum, 2012; Chapman, 1985) deduced that there would also be another transit in the near future, on 24 November 1639 (4 December 1639 CE Gregorian; Whatton, 1859: 43). Horrox planned and

Figure 4 (left): Frontispiece of Kepler's *Tabulæ Rudolphinæ* (1627). It depicts the Temple of Urania, the Muse of Astronomy. Designed by Kepler himself, it is a tribute to great astronomers like Hipparchus, Ptolemæus, Copernicus and Tycho Brahe. Brahe at centre explains to Copernicus (seated) his geocentric world depicted on the ceiling. Hipparchus holds the *Catalogue of Fixed Stars* and *Testament* and Ptolemæus holds an astrolabe. The roof top has six goddesses representing the essence of Kepler's astronomy—optics, geometry, logarithm, laws of balance, the Sun's magnetic force on the planets and magnetism; see Ragstedt (2013) for discussion on the Frontispiece (Google Arts and Culture scan of the British Library copy; Wikimedia Commons).

Figure 5 (below): A portrait of Pierre Gassendi by Louis-Édouard Rioult (Wikimedia Commons).

was able to observe it from Much Hoole in Lancashire using the projection method. Also, his friend William Crabtree (1610–1644) whom he had told about the transit, successfully observed it from near Manchester (Whatton, 1859: 25, 44–45).

Horrox recorded these observations in his

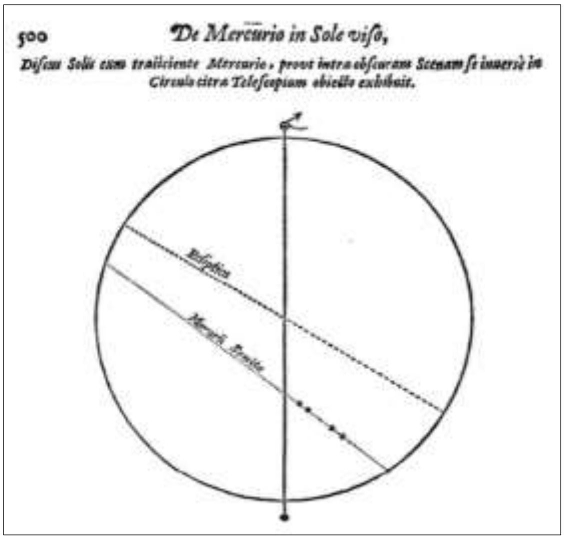


Figure 6: "The disc of the Sun with the transiting Mercury, as within the dark scene it exhibited itself inverted in a circle on this side of the telescope's object." (after Gassendi, 1658(4): 500).

work, *Venus in Sole Visa* … (published by Johannes Hevelius in 1662), where he described Venus on the Sun as a round body of perfect black colour; he also gave its size as 1′ 16″, a great improvement on the figure of 7′ attributed by Kepler; and he reported the angular diameter of the Sun as 31′ 30″. The event also gave him an opportunity to correct the mean motion of Venus; find its node; and correct the inclination of its orbit, to 3° 24′. Horrox concluded that the solar parallax could not be greater than 14″ (Whatton, 1859: 184, 187, 212), a value much smaller than the figure of 57″ that Kepler arrived at (Whatton, 1859: 83). This new parallax value corresponded to a mean Earth–Sun distance that was substantially larger (~15,000 times the Earth's radius) than the one adopted at that time, and so it had attendant implications for the canonical worldview.

3.2 The Transit of Mercury of 1631

Pierre Gassendi (1592–1655 CE; Figure 5) was an astronomer, mathematician and philosopher with a doctorate in theology. The French Catholic priest successfully watched the transit of Mercury from Paris on 7 November 1631 by projecting an image of the Sun with a telescope onto a piece of paper. He was located under a dark roof, which was how he was accustomed to observing sunspots and eclipses. Figure 6 shows Gassendi's depiction of the transit (Gassendi, 1658(4): 500).

The *Admonitio ad Astronomos* referred to in Gassendi (1658) was published by Kepler and his son-in-law Jacob Bartsch in 1630. It was an extract from the *Tabulæ Rudolphinæ* supplemented with the calculated positions of the luminaries. Kepler had also suggested using the projection method with a telescope or a *camera obscura* and, for any possible inaccuracies in the ephemerides, to maintain a watch for a few days in succession. Gassendi did just that. He made a start on 5 November but it rained that day. On 6 November, there was fog and the Sun showed up only for a while. However, the following day he was rewarded:

> When, therefore, the aforesaid day 7 in November, the Sun would already be at a high degree. 21.min. 44. and therefore at 10 o'clock in the morning, with 28 minutes, Mercury passed from the western edge of the Sun, with a latitude, or distance from the Ecliptic towards North, of 6 minutes and 10 seconds. Evidently Mercury was retrograde during that time, and had already passed the node … (Gassendi, 1658 (1), *Liber* 4, Ch. 7: 695).

Gassendi had used a Galilean telescope to project the image of the Sun onto a piece of paper with a circle drawn on it equal to the diameter of a 'Paris foot' (i.e. 32.48 cm). He divided the diameter in 60 equal parts where a division would correspond to 30″ of arc. Gassendi saw the planet make a shadow but, to his surprise, found it much smaller than he was expecting. Comparing with the diameter of the Sun he assessed the tiny spot to be no more than about 20″:

> Moreover, taking into account the thinnest of the rim, this diameter of Mercury could scarcely have exceeded a single part, that is, a third part of a minute, or more than 20 seconds. Wherefore the diameter of Mercury was not seen to be greater than the ninetieth part of the diameter of the Sun. (Gassendi, 1632: 7; 1658: 501; c.f. van Helden 1976: 4–5).

Here was an event the kind of which no one had witnessed before. Though it commenced hours ahead of the prediction, watching the movement of a black spot for several hours convinced Gassendi that it was Mercury transiting the Sun. That made it the most significant observation in astronomy up to that date. The transit provided for the first time an occasion for a quantitative estimation of the physical extent of a planet. In the process, it not only became a check on the prediction of the event but also led to improving the orbital elements.

The following month, on 7 December 1631, Gassendi tried to observe a transit of Venus from Paris but without success—even though he had kept watch during the greater part of three successive days (Gassendi, 1632: 25–28; Whatton, 1859: 17). However, Kepler's *Tabulæ Rudolphinæ* showed that the Contact IV was already over at 06:47 UT, before the Sun rose over Paris (07:34 UT). Gassendi reported his observations of Mercury and Venus in two letters to his friend Wilhelm Schickard, Professor of Hebrew at the University of Tübingensi. The letters were published in Gassendi (1632), and also in his *Opera Omnia* (Gassendi, 1658), titled: "Mercury was seen in the sun and Venus was not seen by the Parisians 1631. For the wish & admonition of Kepler. Two letters with some other observations …"

Note that independent observations of the transit of 1631 were made also by Johannes Remus Quietanus (Barrettus, 1666: 955–956) and Jean-Baptist Cysat (1588–1657) in Ingolstadt using projection of the image with a telescope.

The next transit of Mercury happened on 8–9 November 1644. It was not visible from Europe. It would be the same with the transit that was to be in 1651. The Englishman Jeremiah Shakerley journeyed all the way to India to be able to observe it on 3 November 1651. However, the next transit of 3 May 1661 would be visible in England. It was observed by Huygens, Street and Mercator in London and by Hevelius in Danzig (Hevelii, 1662). Edmund Halley (1656–1742) and a few others observed the next transit on 7 November 1677 from St Helena. In between, a transit of Venus occurred on 4 December 1639, visible through Europe, but it was observed only in England (Whatton, 1859).

The English astronomer William Gascoigne (1612–1644) introduced, by 1640, a crosswire into the eyepiece and a micrometer that transformed the telescope into a powerful measuring instrument. All this was taking place at a time when numerous pioneers of science lived and were active; for a roll of honour see Hughes (2004: 147). Planetary transits were uncommon and in the course of time became so fascinating as to capture the attention of astronomers and the public alike in various parts of the world (e.g. see Holden, 1878, and Figure 7).

4 FINDING PLANETARY TRANSITS IN HINDU ASTRONOMY

Planets begin to feature in Indian texts from around the turn of the first millennium. In the Buddhist Sanskrit text *Divyāvadānam* (200–350 CE; Vaidya, 1959: xi), the Chapter *Śārdūlakarṇāvadānam* is replete with planetary phenomena involving the *nakṣatras*. After verse 33: 232 the text mentions of seven *grahas* by name and in the order—Moon, Sun, Venus, Jupiter, Saturn, Mars and Mercury. The world here is geocentric, where eclipses of the Sun and the Moon are possible but planetary transits are not.

In the *Sūrya Siddhānta* (*SS*), a mathematical astronomy text composed circa 400 CE, the order is: Moon–Mercury–Venus–Sun–Mars–Jupiter–Saturn–fixed stars, supposedly in order of increasing distance from the Earth (*Panchasiddhāntika*, 13: 39); the *Āryabhatiya* (499 CE) by Āryabhatta (476–550 CE) maintains the same order. Here, the transits of Mercury and Venus are possible. In the *SS*, Chapter VII defines a planet's conjunction (*samāgama*), and we encounter (ray-obliteration: *yuddha*) when a planet is vanquished or is victor. The verses VII: 13–14 give the apparent planetary diameters—in *yojana*, but also reduced to minutes of arc (Burgess, 1860).

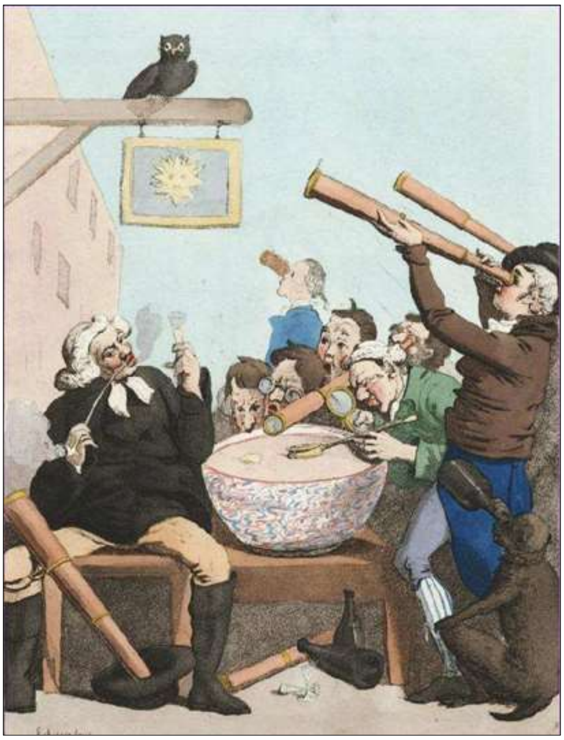


Figure 7: Cartoon of the transit of Mercury of 7 May 1799 in the Lewis Walpole Library, Yale University (after Tobin, 2013: 224–249).

In Varāhamihira's (485–687 CE) *Bṛhat Samhitā* (505 CE; Bhat, 1986: 17), planetary conjunctions are classed as occultations, grazing incidences, etc. A planetary conjunction is *yuti* and the occultation a *bheda-yuti*. In a *bheda-yuti*, the longitudinal separation between two planets becomes smaller than the sum of their radii with the lower planet covering wholly or partly the orb of the higher planet. The situation is then treated akin to a solar eclipse and computations made for contact, immersion, emersion and separation (Shukla, 2000: 236–275). Planetary conjunctions were considered also by Vatéśvara (b. 880 CE) and Utpala (966 CE).

The *Dhruvamānasa* (1056 CE) by Sripati Mishra (1019–1066 CE) is devoted to the computation of planetary longitudes and eclipses (O'Connor and Robertson, 2000). This is the first Indian astronomical work that considers planetary transits. The next is Sripati's *Siddhānta-śekhara*. Interestingly, Sripati was 13 when Venus transitted the Sun on 24 May1032 CE. The transit was not visible, but computations should allude to that. The next transit of Venus happened on 22 May 1040 CE and was visible in India. Similarly, Mercury transited the Sun in 1039 in the afternoon of 3 November. The same year, Sripati's first work, the *Dhikotidakaraṇa*, on lunar and solar eclipses, was composed.

Venus transited the Sun next on 23–24 November 1153 CE when the great Indian mathematician and astronomer Bhāskarāchārya (Bhāskara II; 1114–1185 CE) lived. The *Siddhānta Shiromaṇi*, his *magnum opus*, considers in the *Grahayutyādhikār*a planetary conjuncttions including occultations—as in an eclipse of the Moon or the Sun—and their timing.

Vallālasena (Ballāl Sena), the ruler of Bengal ascended the throne in 1160 CE. He was a learned man who took observations, determined winter and summer solstices and considered celestial phenomena including comets in his tome the *Adbhutasāgara* that he began in 1168 CE (Jha, 2006: 26). Vallālasena died before he could finish it. The work was completed by his son Lakshmaṇasena (1122–1205 CE). The *Adbhutasāgara* is composed along the lines of the *Bṛhat Samhitā*, and has a chapter on the *Grahayuddha* (planet wars) where it defines conjunctions of Venus and the Sun and Mercury and the Sun. Interestingly, the chapter on the Sun refers to situations where a hole occurs in the orb of the Sun even without its being 'occulted' by Mercury or Venus, with attendant ominous repercussions (Jha, 2006: 46–47). It is possible that the reference is to naked eye sunspots. Recall that Korean and Chinese records mention naked eye sunspots seen in 1160 CE and 1171 CE (Yau and Stephenson, 1988).

However, the name that matters in the present context is Kamlākara (b. 1608 in Varanasi; Dikshit, 1981, Part II: 162). He is known for the *Siddhānta-Tatva-Viveka* (1658) that he composed on the pattern of the *Sūrya Siddhānta* (see Dwivedi and Jha, 2009). Its chapter *Biṃbādhikara* is about the visibility of planets and planetary conjunctions. In stanza 28, Kamalākara asserts that:

> I do not agree with the objection raised by certain learned people to the idea that Mercury and Venus create a hole-like appearance on the sun from whom they acquire the brightness. (Rathnasree et al., 2012: 96).

Kamlākara contends that the planets do not shine by their light. He points out how in a conjunction, Venus is quickly lost in the dazzling light of the Sun (heliacal setting) when their separation falls below a certain small angle, the *kalāṃsha*. Kamlākara believed that the hole made by Venus in the Sun could be big enough to be seen. He even remarked that the Greeks had seen the planet Venus transit the disc of the Sun (Dikshit, 1981(II): 164). Kamlākara is so clear that we can only wonder if the young man had even taken note of two such situations developing with Venus, on 7 December 1631 and 4 December 1639 respectively. Besides, Mercury also transited the Sun quite a few times during his lifetime: the transits in 1631 (visible), 1644 (partial), 1651, 1661 and 1674 were visible or partially visible from India.

Sāmanta Chandrashekhar Simha (1835–1904; Figure 8), popularly called Pathāni Sāmanta, was a *Siddhāntic* (theoretical) astronomer in a relatively modern age. He devised a number of instruments to carry out astronomical observations using the naked eye. He brought together his knowledge and experience in the *Siddhānta Darpaṇa*, an invaluable tract in Sanskrit, published in 1899 by the Indian Depository in Calcutta (Naik and Satpathy, 1998). Chandrashekhar's results compare well with the true positions and movements of the celestial objects, including their conjunctions etc., even though he had no exposure to modern scientific works or instruments (Satpathy, 2003).

In the *Siddhānta Darpaṇa* (XI, stanzas 73–75, 110), Sāmanta Chandrashekhar speaks about the situation when the *biṃba* (image) of one planet makes incursion into that of another which should then be considered like other conjunctions. Retrograde *Budha* (Mercury) and *Shukra* (Venus) when their declinations get very small occult the Sun. In Stanza XI: 110, he describes *Shukra* seen eclipsing the Sun in the Kali year 4975, which is 1874 CE. To find the eclipse of the Sun by the planet, their respective sizes are to be stated—it was then 1/32 that of the Sun's *biṃba* which is 650 *yojanas*. Note that *yojana* is a measure of distance. In Indian texts, there is no standard measure of the *yojana*. It is variously estimated and, as evaluated in Burgess (1860: 59–60) and Dikshit (1981(II): 199–200), it is close to 5 English miles.

Naik and Satpathy (1998) state that Chandrashekhar predicted the transit from his computations and observed it with the naked eye. The observation may have been made from Khāndapāḍā (20°.27N, 85°.18E) in the Nayāgarh district in Odisha where he was born. Chandrashekhar's observation is discussed in Kapoor (2014). As we know, the 1874 transit event was widely observed from India.

5 INDIA'S TRYST WITH THE TELESCOPE

Initially, the telescope was put to astronomical use in India only sporadically. After its invention

Figure 8: A painting of Sāmanta Chandrashekhar Simha (courtesy: Institute of Physics, Bhubaneshwar https://www.iopb.res.in/~duryo/Samanta_Chandrasekhar/Picture_1236.jpg).

in Europe in 1609, the story of the 'perspective glass' or *occhiale*, reached Indian shores quickly. Father Antonio Rubino (Antonius Rubinus, 1578–1643), a Jesuit missionary in Goa, heard of the invention, and in 1612 initiated efforts to acquire one from Rome. He is understood to have been the first to introduce the telescope to India (Baldini, 2015; Udias, 2003), although no published account of this is available.

We come across the first published account of a telescope in India when it was used to observe the bright comets 1618 II and 1618 III from Goa by Fr Venceslaus Pantaleon Kirwitzer (1588–1626), who was later joined by Fr. Adam Schall von Bell (1591–1666; Anonymous, 1877). Because of these observations, the Jesuits deserve credit as the independent discoverers of both of these comets, and they also were the first outside of Europe to use an optical device in order to observe comets (Kapoor, 2016). The next known use of a telescope to observe an astronomical event from India dates to 1651—see Section 6.1, below.[2]

6 CHASING MERCURY IN INDIA

After 1631, a transit of Mercury next occurred on 8 November 1644, but its timing was not favourable for India. This, however, was not the case with the next one, in 1651.

6.1 Jeremiah Shakerley and the Transit of Mercury of 3 November 1651

An English mathematician and astronomer named Jeremiah Shakerley (1626–1655; Chapman, 1985; Kochhar, 1989) came to Surat in India especially to observe the 3 November 1651 transit, since it was not visible from Europe.

Shakerley was born in North Owram, in Halifax, Yorkshire, and died in India. He came from a family with an astrological background, but by 1649 he had begun to feel uncertain about the predictions. He educated himself using the works of Kepler, Boulliau and Horrox, and he admired them and felt indebted to them. As Chapman (1985: 11) says,

> Shakerley was the first man to 'discover' Jeremiah Horrocks, and announce his work to the world over a decade before it was formally recognised in London and Danzig.

When Shakerley saw that the 3 November 1651 transit of Mercury would be visible from India he decided to move to Surat. In those days, the long haul out to India via the Cape of Good Hope took about six-months, so Shakerley's journey must have begun around March or April 1651. We don't know which of the various East India Company (EIC) ships plying the Indian route he travelled on, but we do know that he was already in Surat in the autumn (Chapman, 1985).

Apart from the unfortunate fact that the transit would be in progress at sunrise, Surat was an ideal observing site. It was a famous port city for textiles and diamonds (Gokhale, 1979; Rawlinson, 1920) and was located on the banks of the Tapti River near where it enters the Arabian Sea (21° 10′ N, 72° 50′). It was an important commercial and international trading centre.

We do not know Shakerley's observing site, or what telescope and other astronomical equipment he used (Kochhar, 1989). But for reference, we do have the following information on the contact timings (UT): 1651 Nov 03, 1st Contact: 23:07, 2nd Contact: 23:09, Greatest: 00:52, 3rd Contact: 02:35, 4th Contact: 02:38, Minimum Separation: 750.7″ (after Espenak, 2016).

As noted, the transit was already in progress that day when the Sun rose over Surat at 01:15 UT, so Shakerley could only observe the egress. The duration available to him within which to view the event was just 83 minutes.

In the *Astronomia Brittanica*, Vincentio Wing (1699: 312) provides a brief description of the 1651 conjunction. He cross-checked with the ephemerides of the Sun and Mercury to conclude that Shakerley did see it in India, just as it was predicted by him in a colloquium "DE MERCURIO IN SOLE VIDENDO." Wing (*ibid*.) points to the conjunction having been seen by projection behind the telescope:

> In the year of Christ, 1651. On the 24th of October, in the morning, Jeremias Shakerleus, of Surat, East India, observed the illustrious conjunction of the Sun and Mercury, with the help of a telescope, for at 6:40 a.m. he saw Mercury in the circle of the Sun's disc depicted behind the telescope, between the North and the West, and therefore in Heaven it was placed between the South and the East, it was distant; then from the centre of the Sun 10′; hence we gather that the true Conjunction took place in London, hor. 1. 18′ 8″ morning, at which moment, from our Tables, the motions of the Sun and Mercury were like this.

The dates are Julian Days. Wing (*ibid.*) next tabulated the transit circumstances, including the positions of Mercury and the Sun and the timings, adding that

> This Conjunction was foretold by the same D. Shakerleus in his Colloquium, or Disputation, ON SEEING MERCURY IN THE SUN, and afterwards he himself transmigrating to India, saw this remarkable Conjunction there … He communicated with his friends in England, as appears from letters sent to Christopher Towneley, Henry Osborne of London, and others.

Shakerley's discourse "De Mercurio in sole vivendo" is part of his *Almanack for 1651* (Shakerley, 1651) where he provides a calculation of the upcoming transit of Mercury across the Sun due on 24 October 1651 [Julian]. He stresses the rarity and the importance of its observation (Shakerley, 1651: 30, 36), as follows:

> The ingenuous Kepler by a publick Admonition desired all Astronomers to take notice of an appearance in the

> Suns bodie, *viz*., the passage of Mercury betwixt the eye and it; which afterwards fell out, and was accordingly observed by the above mentioned Gassendus, in October 1631 … If this Calculation be true and certain, (as indeed I do much confide in it) we in England shall in-vain expect anything of this appearance; It being rather to be seen by our Antipodes, the Islands of Solomon, the Kingdome of China, the straits of Anian and the parts adjacent.

He goes on to suggest the method of observation to be made with a telescope by projecting the image of the Sun onto a sheet of paper duly graduated in the same way that Horrox had done. These observations would make it possible to define Mercury's orbit that he says is elliptical, and fix the location of the node and, most importantly, "… without fear of error, or danger of fallacie … an exact comparison of the diameters of the Sun and Mercury." (Shakerley, 1651: 39).

In his letter of 15 January 1652 to Henry Osborne in England Shakerley presented further details of his transit observations (see Chapman, 1985). He regretted having no proper instruments but did admit that what he had was better than a half-crown perspective. Thanks to the trying conditions of his stay, he was able to get just one sighting of the Sun's disc but still could note Mercury as

> … the colour of a brownish black and the diameter very small, as I am confident that it did not exceed half a minute. (Chapman, 1985: 7).

His letter included a diagram showing the planet's position in the Sun's disc.

In his letter to Osborne, Shakerley also described his observations of a lunar eclipse on 7 September 1652 and a comet in 1652 (Chapman, 1985: 8).[3] Shakerley found his stay in India a great learning experience. He was fascinated by the Brahmin astronomers whose calculations predicted the lunar eclipse with little or no error, and he also learnt about the Indian calendar (*ibid*.).

By the time he died, in India in 1655, Shakerley's published works comprised *The Anatomy of Urania Practica* (1649), *Synopsis Compendiaria* (1651); his Almanac for 1651, and *Tabulæ Britannicæ* (1653). Much later, in 1878, a columnist in *Nature* mentioned Shakerley's observations of the transit in India and Wing's (1669) reference to it, but wondered why none of Shakerley's works was available in the libraries of the British Museum, the Royal Observatory or the Royal Astronomical Society, whereas his *Tabulæ Britannicæ* was in the libraries of the Royal Society and Cambridge University (Anonymous, 1878). Chapman (1985, 1990) and Baker (2020), and references therein, provide more information about Shakerley and his work, and about letters of his in the Bodleian Library.

7 MODERN ASTRONOMICAL ACTIVITY IN EIGHTEENTH-CENTURY INDIA

Astronomical observations were made in India from time to time by the Jesuit missionaries and the English surveyors, mainly in order to determine latitudes and longitudes of sites (Phillimore, 1945(1): 153–154).

A new era in astronomical activity commenced in India when the British, fresh from their victory in 1757 at the battle of Plassey (Palashi), initiated scientific surveys to get an accurate geographical knowledge of the land. By 1765, the EIC had more or less taken over all of Bengal. In the 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 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, and placed 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, and he incorporated the valuable work carried out by Fr. Tiefenthaler over a span of about thirty years in the 1788 edition of his *Map* (Phillimore, 1945 (1): 1–9).

On 15 January 1784 the Asiatic Society was founded in Calcutta by Sir William Jones (1746–1794), Judge of the High Court in Bengal, and a few others to promote scientific discussions and "… for the purpose of inquiring into the History Civil and Natural, the Antiquities, Arts, Sciences, and Literature of Asia …" (Anonymous, 1788: 5). Soon, the first modern astronomical observatory was constructed in Madras (now Chennai). It was a private one, established in 1786 by William Petrie (1747–1816), an officer with the EIC. This was the most significant beginning of modern observational astronomy in India as it eventually evolved into the Indian Institute of Astrophysics (IIA). Petrie possessed three 2¾-inch achromatic telescopes of 3½ feet focus by John Dollond, a quadrant by Bird, a 20-inch transit instrument by Stancliffe, and an astronomical clock with a compound pendulum by John Shelton (similar to one that was used by Captain James Cook during the 1769 transit of Venus expedition) that was moved to Kodaikanal Observatory in 1900 and is still ticking (Kochhar, 1985: 164). Longitudes were determined from observations of Jovian satellite phenomena. The first such observations on record, on page 164 in the *MS Observations* at the Indian Institute of Astrophysics Archives, date from 5 December 1786 and relate to the determination of the co-ordinates of Masulipatam Fort flagstaff by Michael Topping (Kochhar, 1989b). In 1789, the EIC took over Petrie's observatory and in 1792 it was moved to new premises at Nungambakkam (which is also in Madras). It was designed by the Company's new astronomer and marine surveyor Michael Topping (1747–1796), and renamed Madras Observatory (see Kapoor and Orchiston, 2023).

7.1 Fr. Tiefenthaler and the Transit of Mercury of 4 November 1743

Fr. Joseph Tiefenthaler (1710–1785) was a Jesuit missionary, and also an astronomer, geographer and historian. He was born in Bozen in the country of Tyrol then in the Austrian Empire. He entered the Society of Jesus in 1729 and was sent on the East Indian mission in 1740 by his religious superiors (Huonder, 1912) to join the Jesuit astronomers at Mahārājā Sawāi Jai Singh's (1688–1743) Vedhashālā in Jaipur. He landed in Goa in 1743 but the Mahārājā's passing away on 21 September (Bahura, 1979: 146) that year dented his plans. He was then asked to proceed to Agra to give his services at the Jesuit College. In 1747, he moved to Narwar in the Shivpuri district to begin service as a priest, and remained there until 1765. After the suppression of the Society of Jesus, Tiefenthaler stayed on. He travelled extensively in Northern India and between 1743 and 1773 he built up his record of astronomical observations and geographical surveys (Maclagan, 1931: 137–141).

Fr. Tiefenthaler understood several languages, including Persian, Arabic, Hindustani and Sanskrit, and he even prepared a Sanskrit–Persian dictionary. He wrote on contemporary history of India, religious life, the natural sciences, geography, and flora and fauna. His work *Descriptio Indiæ* translated from Latin into French (*Description Historique et Geographique de L'Inde*) by the mathematician–astronomer Johann III Bernoulli (1744–1807) appeared in Berlin in three volumes (1786–1791). In it he presented a description of 22 Indian provinces—the cities, towns and the forts, along with several sketches and maps giving the geographical positions that he obtained with a quadrant.

The quadrant is a simple but important scientific and mathematical instrument with a graduated arc and a stereographic projection of the celestial sphere that was used by geographers, navigators and astronomers for determining time of the day, the Sun's or a star's altitude, azimuth, right ascension and declination, and position on the ecliptic. Leybourn's (1731) manual is an excellent guide for Edmund Gunter's portable quadrant. Fr. Tiefenthaler laid great emphasis on the determination of longitude and latitude of places in India as being fundamental to knowing its geography correctly. Sen (1982) discusses Tiefenthaler's efforts at length, and mentions that the Jesuit made use of a brass astronomical quadrant and also an astrolabe (also see Mukherjee, 1985: 59). Phillimore (1945(1): 150) cites Fr. Noti, S.J. about Fr. Tiefenthaler's astronomical observations.

Fr. Tiefenthaler had observed the transit of Mercury of 4 November 1743 from Goa. Here is his own brief description of the event:

> In 1743. On the 5th (a) at about two o'clock in the afternoon, I saw Mercury pass over the disk of the Sun, like a burning coal. But Astronomy will not draw any fruit from this observation, because lacking astronomical instruments, I was unable to observe either the beginning or the end of the passage.
> (a). The author forgot the month; which was *November*, and it should have been the *4th*. (Bernoulli, 1786(1): 511).

In Espenak (2016), the contact timings (UT) of the transit are listed as: 1st Contact: 08:12, 2nd Contact: 08:15, Greatest: 10:30, 3rd Contact: 12:45, 4th Contact: 12:47, Minimum Separation: 542.4″

The location where he observed from is not specified. However, the above passage appears just below his description of the Jesuit College of Rachol in the southern peninsula of Salsette that he says is "… a place equipped to protect against enemy incursions, by means of a castle, a wall, a rampart and a moat." Rachol has been home to the Patriarchal Seminary of Rachol since 1610, and was built by the Jesuits atop a hillock (Figure 9). Fr. Tiefenthaler gives the latitude of this place as 15° 10′ N. Rachol is where the two November 1618 Great Comets were observed by Fr. Venceslaus Kirwitzer and his brother Jesuits (see Section 5).

The transit apart, Fr. Tiefenthaler made a few other astronomical observations while in

Figure 9: The Patriarchal Seminary at Rachol, Goa (photograph: R.C. Kapoor, 12 November 2018).

India. Briefly mentioned in *Descriptio Indiæ* are an occultation of Jupiter by the Moon on 2 February 1744 (Bernoulli, 1786(1): 10); Chéseaux's beautiful multi-tailed comet (C/1743 X1) in 1744 (Bernouli, 1786(1): 3); the (partial) lunar eclipse of 26 April 1744; sunspots and the zodiacal light (Bernoulli, 1786(1): 7; Huonder, 1912). Fr. Tiefenthaler also prepared a 15-ft long map of the river Ganges (De Souza, 1994: 179–180) and of the Gagra system, a testimony to his passion for geography and cartography.

During his time in India, Fr. Tiefenthaler visited Mathura in 1745 to see Mahārājā Sawāi Jai Singh's Observatory and in 1750 the observatory at Ujjain (see Bernoulli, 1786(1): 316; Phillimore, 1945(1): 151; Sen, 2000: 65).

The next transit of Mercury took place in 1753, and was visible from India.

7.2 Fr. Coeur-doux and the Transit of Mercury of 5 May 1753

In a detailed report for the year 1753, the journal *Histoire de L'Academie Royale des Sciences Année 1753* (*L'Academie Royale*, 1757: 228–240) brings together the observations of the transit by many astronomers in Europe. However, observations of the transit by the Jesuits in Pondicherry figure nowhere in the journal, or in any later volume.

So, who at Pondicherry were the observers of the said transit of Mercury, and are there any records or references, say, in letters sent back to Europe (as was the convention among the Jesuits)? The name that immediately comes to mind is the French Jesuit Gaston-Laurent Coeur-doux (1691–1779). Upon searching, we found that Coeur-doux did observe the transit, together with Friar Jean-Baptiste du Choisel (1717–1793), the Professor of Hydrography in Pondicherry (Restif-Filliozat (2019: 82). However, Restif-Filliozat does not mention his source(s). We know that du Choisel came to Pondicherry in 1740. The private diary of Anada Ranga Pillai, Dubash (interpreter) to Joseph Francois Du-pleix, the Governor of Pondicherry, dated Saturday, 5 May 1753, describes events on that day, but it makes no mention of the transit (Dodwell, 1922: 328).

Gaston-Laurent Coeur-doux was a Jesuit missionary, naturalist and linguist, and the first to demonstrate a similarity between Sanskrit, Latin and Greek, and also German and Russian, well before the British Orientalist Sir William Jones did so in 1786. He is acknowledged

Figure 10: Pondicherry was an affluent Indian city with active involvement in astronomy. Here is a view of the port area, showing the warehouses of the French East India Company, the Admiralty and the Governor's House (Lithograph: *Institut de Mécanique Céleste et de Calcul des Éphémérides*, https://vt2004.imcce.fr/CDs/CD-VT-histoire/html/textescommentes1761.html).

in the *Moeurs et Coutumes des Indiens* (*Morals and Customs of the Indians*; 1777), which was the first Indology treatise (Murr, 1987). He was ordained in 1725, and came to India and served in the Madurai Mission from 1732 to 1773. From 1737, he was based in Pondicherry. In his diary chapter for mid-July 1746 Ananda Ranga Pillai wrote that Fr. Coeur-doux was the Superior of the Church of St. Paul (Price, 1907: 109). In 1748, Fr. Coeur-doux established the Carmel Convent in Pondicherry. Figure 10 shows the busy port of Pondicherry.

While at Pondicherry, Fr. Coeur-doux made a number of astronomical observations. The Reverend William Hirst (1761–1762), who had observed the 1761 transit of Venus from Madras was aware that there were Jesuits in Pondicherry who also had observed the event but he did not name them. In fact, there was only one of them, and he was Fr. Gaston-Laurent Coeur-doux (Kapoor, 2013b: 280).

Fr. Coeur-doux also observed the Great Comet of 1759 in March–April; in a few years' time this would become known as 'Halley's Comet'. The observations were made with the help of a semi-circle ten inches in diameter placed perpendicularly on a circle of the same size, and using an 18-inch telescope (Coeur-doux, 1766: 458–460). While describing his observations, Coeur-doux refers to the unreliable watch he was using that had belonged to Fr. Claude Boudier (Kapoor, 2018), a deceased French Jesuit astronomer who had arrived at the French mission at Chandernagore in the Hooghly District in 1719.

After 1753, the next transit of Mercury visible from India occurred in 1756.

7.3 Indian Observations of the Transit of Mercury of 7 November 1756

Although the transit of 7 November 1756 (Espenak, 2016) was observed in Pondicherry there is no published account of it, and all we have is one peripheral reference to it in *Histoire de L'Academie Royale des Sciences Année 1758*. While reporting on this transit De L'Isle (1763: 134) says:

> This last transit of Mercury over the Sun, which the clouds prevented from being seen in Paris, was observed in seven different places, namely, Marseilles, Florence, Rome, Berlin, Wittenberg in Saxony, Pondicherry and Peking. (my English translation).

Unfortunately, De L'Isle (1763) does not report on the Pondicherry observations or name the astronomer. We suspect that it was Fr. Coeur-doux.

The next transit that was observed from India occurred in 1799.

7.4 Dr. Dinwiddie, Captain Pavin and the Transit of Mercury of 7 May 1799

The transit of 7 May 1799 was a very long duration event of 7h 31m. It was the fifth one observed in India.

Someone who tried to observe the transit was Raja Gopee Mohun Deb (1763–1837; Figure 11) with guidance from Dr. James Dinwiddie. The Raja, who belonged to the Sobhābāzār Rājbāri, a Royal Family of Bengal, borrowed a telescope from Dr. Dinwiddie.

The Sobhābāzār Rājbāri is a Royal Palace in North Calcutta (now Kolkata), built by Raja Nabakrishna (Nubkissen) Deb Bahadur (1733–1797) in the mid-eighteenth century. He was associated with the administration of Robert Clive. Deb was his Persian Secretary and Diwan and, as his close confidant, had helped the British in laying the foundation of an Empire. After the fall of Nawāb Sirāj-ud-Doulā (1733–1757), the last independent king of Bengal in the battle with the EIC at Plassey (Palashi) in 1757, Nabakrishna quickly grew to be very influential, made a huge fortune and acquired property in Calcutta (Deb, 1905: 2). He initiated the iconic Durga Puja celebrations in October–November, beginning in 1757 after the British victory on 23 June, and with Robert Clive present as the chief guest. This has continued ever since as an annual socio-religious tradition. In 1766, Raja Naba-krishna Deb was conferred the title of Maharaja for his services and loyalty. In 1768, he adopted Gopee Mohun Deb, the son of his brother Ram Sundar Deb (Ghose, 1901: 204).

Dr. James Dinwiddie (1746–1815; Figure 12) was a natural philosopher, astronomer, inventor and mathematician. He was an itinerant lecturer in mathematics and the sciences and extensively travelled. He became part of Lord George Macartney's mission to China in 1792 to promote trade, strengthen connections between the two empires and give presents that signified British scientific achievements. The mission did not achieve its goal, and Dinwiddie chose to go to Calcutta in 1794, and he stayed there until 1806. He soon established himself as a public lecturer on natural philosophy and chemistry, galvanism and particularly in areas that related to and could be beneficial to the affairs of the EIC (Proudfoot, 1868: 98, 102):

> Dr Dinwiddie … became … the centre or focus of philosophy in the East. His correspondence was very extensive, and bears ample testimony to his zeal, in promoting researches in every branch of science, and the assistance he lent to those desirous of acquiring information on subjects connected with it. Astronomical and meteorological observations, governmental surveys, mineralogical discoveries, and discoveries made in translating ancient Hindoo manuscripts, formed interesting features in his correspondence ...

Soon after he settled in Calcutta, Dinwiddie was elected a member of the Asiatic Society. He gained a reputation among the Brahmins

Figure 11: Raja Gopee Mohun Deb (http://www.sovabazarrajbari.com/forefathers.html; accessed 27 April 2016).

who at one time visited his lecture room regarding a specific eclipse of the Moon. They could not agree among themselves whether the Moon would be in eclipse before or after the Moon rose. This was important for the rituals dependent on this aspect. Dinwiddie informed them that the Moon would rise eclipsed, about twenty minutes after the commencement, just as was actually observed (Proudfoot, 1868: 102–104).

Dinwiddie received patronage from Marquis Wellesley (1760–1842), a statesman who would be Governor-General of Bengal during 1797–1805 and responsible for extending the British control in India through various wars against Indian rulers. Dinwiddie became Pro-

Figure 12: Dr James Dinwiddie (Wikimedia Commons).

fessor of Experimental and Natural Philosophy, Mathematics and Chemistry in 1801 at the newly formed College of Fort William. He taught both Europeans and elite Indians (Nair, 2013: 66), and he also continued his popular public lectures.

His Indian students included Hurree Mohun, "… the author of several learned translations …", and Gopee Mohan Deb, to whom he taught mathematics and astronomy in 1795. The Raja himself was a scholar in Farsi, founder of the *Dharma Sabha* and, together with the Scottish watchmaker turned philanthropist David Hare (1775–1842) and three others, the founder Director of the Hindu College (which became Presidency College in 1855) in Calcutta, the first institution of modern learning in the subcontinent since 1817:

> … the primary object of the institution is the tuition of the sons of the respectable Hindus in the English and Indian languages, and in the literature and science of Europe. (Deb, 1905: 79).

Table 1: Circumstances for the 7 May 1799 transit of Mercury (after Dinwiddie, 2009).

Transit Circumstances	Time (p.m. mean time)		
	h	m	s
Ingress (beginning)	02	58	43
Interior contact	03	02	05
Sun sets	06	31	40
Mid-transit	06	42	46
Second interior contact	10	23	27
Egress (end)	10	26	49
Duration	07	28	06

Dinwiddie kept many personal scientific journals of his observations and experiments. From the numerous lecture notes, reports of experiments, correspondence and personal journals that he left behind, his grandson, William Proudfoot (1868), was able to bring out Dinwiddie's biographical memoirs. In these, there is a mention of Raja Gopee Mohan's visit:

> I received a visit from Gopee and Hurree Mohun. The former asked me, whether there was any other in England as learned as I am!! In making this compliment, it was to borrow a telescope to observe the transit of Mercury. Divination and witchcraft infect all classes from the highest to the lowest in the land. Hurree Mohun believes in palmistry, the rules of which he knows, and tried them on my hand. When told that such predictions sometimes failed, his answer was ready—*an error in the calculation*. (Proudfoot, 1868: 105).

As per Dinwiddie's *Journal* for the period 29 April 1799–5 July 1799 (Dinwiddie, 2009), the above visit was on 4 May. Recall that over the generations, the Debs acquired proficiency in English, having continuing interactions with nobility, diplomats and senior public servants among the British in Bengal. It is therefore natural to ask:

> What did the transit actually mean to them, that they came so far as to know about it and wished to witness it?

Apparently, the trigger lay in Gopee Mohun's exposure to modern astronomy and the transit circumstances posted by Dinwiddie in the *Calcutta Gazette* on 25 April 1799. This was lucid enough to arouse curiosity amidst the educated elite:

> Mercury will enter the Sun's disc near his vertex. He will appear very dark, perfectly circular, and well defined: by which he may easily be distinguished from a solar spot, should there happen to be any in the neighbourhood at the time. He will cross the disc to the southward of the centre, from which his least distance will be 5.32. (Dinwiddie, 1868a).

Presumably, it was explained to the Royal guest how the telescope should be used, and that one should never view the Sun directly through it but instead use the standard projection method. However, Dinwiddie's Journal entry for 13 May says that Hurree Mohun did not see the transit.

That said, Dinwiddie (1868b) did succeed in observing the transit from Calcutta. The local circumstances were published in the *Calcutta Gazette* on 25 April, and indicated that the transit was to be at the descending node and visible. Dinwiddie took the orbital elements from Lalande's *Astronomy* (1792) and computed the timings listed in Table 1.

He noted a difference of over an hour and a quarter from the times deduced from the *Nautical Almanac* for the year 1799, and was in doubt "… whether the error is to be charged to the British or Bengal calculation, the transit itself must determine." He also gave useful information for the prospective observers, like—to be equipped with a micrometer, the telescope having magnifying power of 80 or 100 or more, and that the observer be ready 20 or 30 minutes before the computed time of the beginning. Dinwiddie (1868a) stressed that

> The most material observation to be made is the interior contact, or the instant of time when Mercury is entirely on the Sun's disc, and the limb above him begins to appear again complete. This is the most useful phase of a trans-

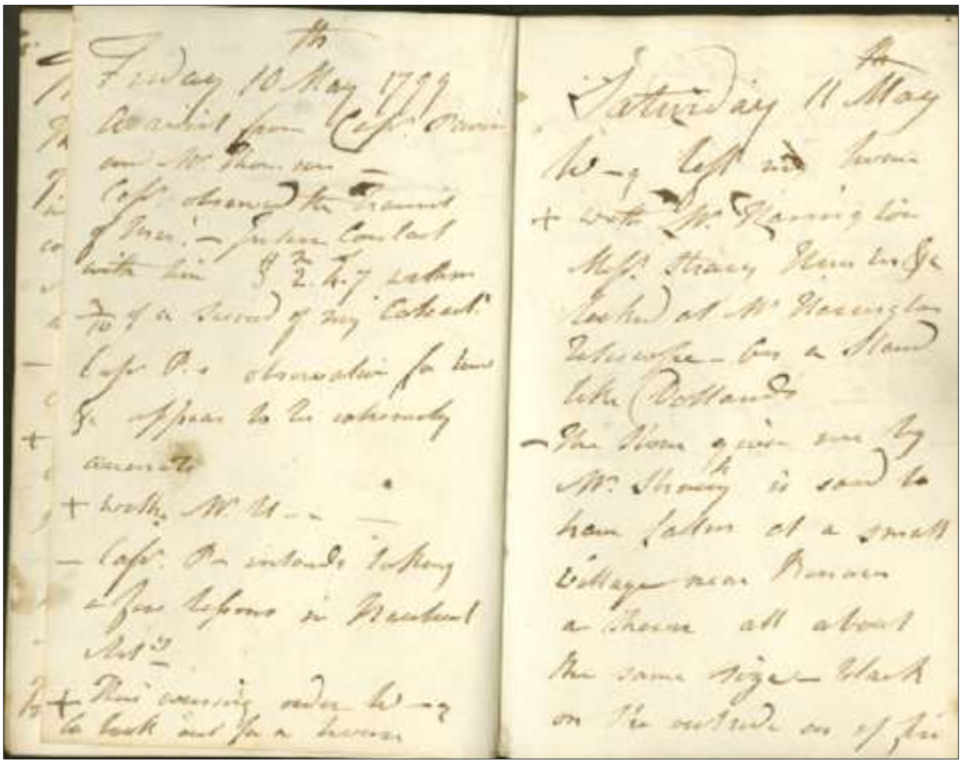


Figure 13: Dinwiddie's *Journal* page, dated Friday 10th May 1799 (after Dinwiddie, 2009).

> it, and may be observed to a much great greater degree of accuracy than any other.

During the observations, Dinwiddie was assisted by two friends, at his house in Cossitollah (later Bentinck) Street, with telescopes having powers ranging from 80 to about 250. One telescope was a 3-feet reflector, "… furnished with Dollond's last improved glass Micrometer." The timings were noted and adjusted to the meridian of Calcutta. His communication appeared in *Calcutta Gazette* on 9 May and is reproduced below:

> The time was given by a Regulator, which had been previously adjusted to the Meridian of Calcutta, and might be depended on to a single second. The interior contact, which was seen almost at the same instant by the three observers, took place

	H.	M.	S.
At	3	1	50
Time by calculation	3	2	5
Difference	0	0	15

> Now, by allowing for a possible error of half a minute in observing, it appears that the observed agreed with the calculation within less than one minute. The error in the Nautical Almanac amounts to one hour and twenty minutes. (Dinwiddie, 1868b).

Meanwhile, the timings (UT) in Espenak (2016) are: 1st Contact: 09:07; 2nd Contact: 09:10; Greatest: 12:50; 3rd Contact: 16:31; 4th Contact: 16:34; minimal separation: 339.5″.

Dinwiddie also measured the distances of Mercury's eastern limb from the Sun's nearest limb with the micrometer and deduced Mercury's diameter to be 12½″. In his *Journal* that covers the period 29 April–5 July 1799 (Dinwiddie, 2009), the page dated 9th May talks of his transit observations appearing in the day's *Gazette* but "… incorrectly printed." The error actually lay in the degree symbol that was printed in place of arcseconds in the observed data. Dinwiddie (*ibid.*) adds, "Mr Hunter called and took away his telescope—sent the observns: to the Post."

This reference is probably to Mr William Hunter (1755–1813), an anatomist and Secretary to the Asiatic Society through 1798–1811 (*Asiatic Researches*, 1799: Volumes 5 and 6). Hunter also made astronomical observations during 1792–1794 (*Asiatic Researches*, 1799: Volume 4), and in 1800 he was on the committee that inspected instruments acquired from Dr. Dinwiddie for William Lambton's survey (Phillimore, 1945(1): 340).

The *Journal* entry dated 10 May (Figure 13) mentions a visit from a Capt. Pavin and Mr Thomson.[4] They also had observed the transit. Dinwiddie quotes the internal contact as being at

> … 3h 2m 4.7s within 3/10 of a second of my calcul. Capt. P's observation for time … appears to be extremely accurate.

Their location at the time of the observation is not given.

Dr Dinwiddie realized that India had a climate favourable for the observation of celestial phenomena such as eclipses, occultations and transits that happened at different times but often were missed in Europe. To cultivate practical astronomy, there needed to be fixed instruments so that the corresponding observations could be made. In a letter dated 19 March 1804 to the Chief Secretary to Government, he made a strong case for the establishment of an astronomical observatory in Calcutta, together with instruments that could record atmospheric phenomena (Proudfoot, 1868: 114–115).

Although the next transit of Mercury, on 9 November 1802, was visible from India, there is no evidence that anyone—even those at Madras Observatory—observed it. The next such transit occurred in 1815.

8 NEW OBSERVATORIES IN NINETEENTH CENTURY INDIA

A few new astronomical observatories were founded in the nineteenth century in different parts of India.

Colaba Observatory was established by the EIC in 1823 for astronomical observations and time-keeping, but little was achieved there until 1841 (Anonymous, 1926: 3–4).

Next the EIC established an observatory in Calcutta, in 1825. It was a small observatory set up at the insistence of V. Blacker (1778–1826), the Surveyor General of India, to serve the Survey Department. It began with an altazimuth circle and a transit telescope, a zenith tube and Kater's pendulum, but soon acquired an astronomical telescope. The observations carried out there included the occultations of stars by the Moon and eclipses of the Jovian satellites. The main activities, however, were time-recording and meteorological observations. Markham (1878: 327) mentions astronomical observations made in the period from 1821 to 1827 by the Surveyor General, Colonel John A. Hodgson, who also was an astronomer. Hodgson determined the longitudes of Calcutta, Madras and 'Puttchgurh' from observations of the Moon and eclipses of Io. His results for the longitude of Madras (5h 21m 8.64s) differed from those of Goldingham (5h 21m 9.4s) by less than one second of time.

Major James Darling Herbert (1791–1833) was also involved in the setting up of an astronomical observatory at Lucknow in 1831. This was for Nawāb Nasiruddin Haidar, the King of Oudh (Awadh), who reigned between 1827 and 1837. The King had a great interest in astrology and astronomy, and was committed to advancing science in India (Kochhar and Orchiston, 2017: 725–727). Many observing programmes were undertaken by Lieutenant Colonel Richard Wilcox (1802–1848), who succeeded Herbert (Phillimore, 1955), but when Wilcox also died prematurely, in 1848, the observatory was shut down (Kochhar and Orchiston, 2017: 727).

Finally, an observatory was founded in Trivandrum (now Thiruvananthapuram) in 1837 by Maharaja Swāthi Thirunal of Travancore. The Maharaja was a great patron of science and was deeply interested in astronomy and he furnished the observatory with the best of English astronomical instruments. He also appointed an English amateur astronomer, John Caldecott as observatory director. Details of Trivandrum Observatory and Caldecott are provided by Orchiston (2025) and Orchiston and Kapoor (2023).

Astronomical developments during this period are described in a series of papers by Kapoor and Orchiston (2023), Orchiston and Kapoor (2023; 2024), and Kochhar and Orchiston (2017).

8.1 Captain Hodgson and the Transit of Mercury of 11 November 1815

We could find one reference to the transit of 1815, virtually lurking in the literature of the times. It was in the volume of the *Asiatick Researches* published in 1822. The reference was part of a communication from Captain John A. Hodgson on the latitudes of places in Hindustan, and the Northern Mountains, with observations of longitude in the Mountains according to immersions and emersions of Jupiter's satellites (Hodgson, 1822b). The latitudes were deduced from the meridian and circum-meridian altitudes of the Sun and stars with sextants and Troughton's reflecting circles and trigonometrically. The telescope he had used for the satellite observations was a Dollond 42-inches achromatic refractor, aperture 2¾ inches, having a tall stand and rack work for slow motion (Hodgson, 1822a: 61). He also had a marine chronometer by Molineux of London.

The description of the transit is very brief (Hodgson, 1822b: 164) and is given in the line concerning the latitude of Dalmow (26° 3′ 58″ N). Hodgson remarks:

> Transit of Mercury. The preceding limb of the planet going off, touched the sun's exterior limb, at mean time 22h 15m 44s 40th. 5. 11th November, 1815.

Dalmow (Dalmau) is a town in the district of Raebareli, and is situated on the banks of the Ganges River. From Espenak (2016), the transit circumstances (UT) are: 1st Contact: 00:18, 2nd Contact: 00:20, Greatest: 02:33, 3rd Contact: 04:46, 4th Contact: 04:48, Minimum Separation: 556.1″.

John Anthony Hodgson (1777–1848; Figure 14) was from the Bengal Infantry, and was a keen surveyor. Phillimore (1954(3): 461) writes that Hodgson

> … had always been an enthusiastic astronomer, and never missed an opportunity of taking obsns [which he published in India and England, and] … provided himself with the very best instruments suitable for fieldwork, read up all the most advanced textbooks, and eventually acquired a wide reputation as astronomer. (Phillimore, 1950 (2): 193).

Hodgson served as Surveyor General of India during 1821–1823 and 1826–1829.

In this context, a letter in *The Observatory* by the British amateur astronomer, the Reverend S.J. Johnson is of interest. He discusses the transits of Mercury of 1815 and 1835 (Johnson, 1904), pointing out that the former event was favourably placed for observing from India. He then quotes from Frend's "Evening Amusements" for 1815:

> It would not be beneath the dignity of the East India Company to give notice of this event … Benares was famous, formerly, for its observatory, and India possesses Europeans of distinguished mathematical talents, on whom, we may be persuaded, this phænomenon will not be lost. The governments of Europe patronised the travels of astronomers to observe the transits of Venus, and it will be an honour to the East India Company if it should be the first to produce to the world an accurate account of the transit of Mercury.

Alas, this did not happen: Johnson (1904) says that on applying to the India Office for any information about this transit he was informed that there were no records of any Indian observations (even by staff from Madras Observatory).

Mercury next transited the Sun in 1822.

8.2 Multiple Observations of the Transit of Mercury of 4 November 1822

There were observations of this transit by a number of observers from different locations in India. The Asiatic Society published in Volume 15 of *Asiatic Researches* extracts of the astronomical observations of the transit from the *Proceedings of the Benares Corresponding Society* in 1825.

Walter Ewer observed the transit from Kurnal (Karnal) with a 5-feet focal length telescope by Dollond with 100× and dark glasses in the eyepiece (Hodgson, 1825, 1827: 110). William Cracroft made observations from Jionpoor (Jaunpur), Lieutenant Maxwell from Meerut and Captains Hodgson, Herbert and Schalch from

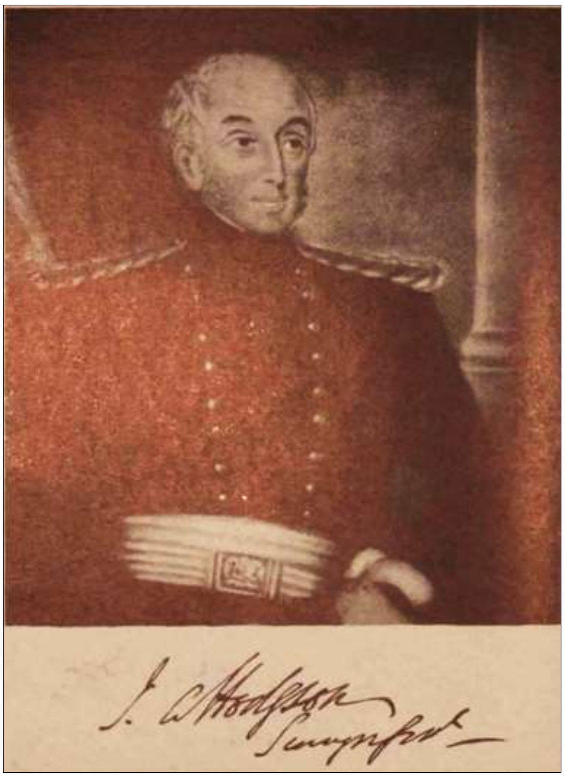


Figure 14: John Anthony Hodgson (after Phillimore, 1954(3): Plate 21).

Calcutta. The differences in the mean times at these places enabled them to determine the longitudes of the observing sites with respect to Greenwich (see Table 2). The following details are from Hodgson (1825):

> As the effect of parallax for the above four places is small, from the displacement of Mercury being nearly in the direction of the tangent to the sun's disc at the point of Emergence, the longitudes of the places, found by the differences of mean time, will not be far from the truth.

Taking 5h 53m 30s as the longitude of Calcutta according to Captain Schalch's observa-

Table 2: A summary of known observations of the 4 November 1822 transit of Mercury made from India.

Observed at Kumal by Mr. Walter Ewer			h. m. s.
Mean time of 2nd internal contact			20 43 46.5
External ditto			20 56 16.5
Difference			2 30
End of transit ☿'s centre			20 55 01.5
Observed at Jionpoor by Mr William Cracroft			
Mean time of 2nd internal contact			21 16 08
External contact			21 18 48
Difference			2 40
End of transit of ☿'s centre			21 17 28
Observed at Meerut by Lieutenant Maxwell, with an inferior telescope.			
Mean time of 2nd internal contact			20 57 17.2
External contact			20 59 03.6
Difference			1 46.4
End of transit of ☿'s centre			20 58 10.4
Observed at Calcutta	Captain Hodgson	Captain Herbert	Captain Schalch.
	h. m. s.	h. m. s.	h. m. s.
Apparent solar time of 2nd internal contact	21 54 49.1	21 54 57.1	21 55 01.8
external ditto	21 57 01	21 57 10	Uncertain.
Mean end of Transit	21 55 54.5	21 56 03.1	21 56 14.8
Corrected Time		21 56 04.1	
Greenwich Time		16 02 17	
Longitude of Calcutta		5 53 47.1	

tions, the longitude of Jionpoor was 5h 31m 09s, Meerut 5h 11m 51.4s and Kurnal 5h 08m 42.5s east of Greenwich. The longitude of Jionpoor by an emersion of Jupiter's first satellite on 20 December 1822 was 5h 31m 08s.

Captain James Dowling Herbert (1791–1833) was from the Bengal Infantry. He and Hodgson, authored "An account of trigonometrical and astronomical operations for determining the heights and positions of the principal peaks of the Himalaya Mountains" which was published in 1822 in the *Asiatick Researches*. William Cracroft, together with James Prinsep, had determined the latitude of the Hindu Observatory at Benares. Walter Ewer (1784–1863), FRGS, was the son of a Governor of the settlement at Bencoolen, and was elected a Fellow of the Royal Society (of London) in 1840. Back in 1803 he had joined the Bengal Civil Service, where had a distinguished career (Buckland, 1906: 141). Ewer had deep interests in music and astronomy. During his visit to Delhi in 1822, he used a telescope of high magnifying power to read for the first time the inscriptions on the Qutub Minar that was then in too a bad state to allow any access (Ewer, 1822: 480–489).

Reporting from Russell Street, Chowringhee in Calcutta, Major J.A. Hodgson (1827: 109–110) communicated his observations of the transit. There were occasional clouds but observations of Mercury's limbs were made under favourable circumstances. Remarkably, the sunlight was so weak that no filter was used in the eyepiece. The planet's disc was dark, round and well defined. Hodgson (*ibid*.) published the following details:

Internal contact, Ingress of following limb,
18h 56m 16,38s
Do. do., at egress 21 38 34,11
External do., at egress 21 40 56,11
Mean time: estimated longitude 5h 53m 10s

For reference, Espenak's (2016) transit timings in UT are: 1st Contact: 01:00, 2nd Contact: 01:04, Greatest: 02:25, 3rd Contact: 03:45, 4th Contact: 03:49, Minimal separation: 838.8″.

Captain Herbert, who was at the same place as Hodgson did not see the start of the event. He used a 42-inch long telescope with an 80× eyepiece and no filter. He also took micrometric measurements with a Dollond parallel wire micrometer using the same telescope. In the same issue of the *Memoirs of the Astronomical Society of London* Hodgson (1827: 110–112) also reported his observations of lunar occultations and of Jovian satellites.

Note that there is no published indication that the transit was observed from Madras Observatory.

Mercury transitted the Sun next in 1832.

8.3 Multiple Observations of the Transit of Mercury of 5 May 1832

This transit was widely observed in Europe, as evident in the communications in Volumes I–II of *Monthly Notices of the Royal Astronomical Society* (1832–1833). Indian observations were made from Calcutta (Kolkata), Barelly (Bareilly), Chupra (Chhpra) and Madras.

James Prinsep (1799–1840; Figure 15) observed from Calcutta with help from Lieutenant Andrew Waugh (1810–1878; the successor to George Everest), and an engineer named Rennie. He had the opportunity to use the very fine 4-feet long equatorially-mounted refracting telescope of Lieutenant Pemberton, 4-inches aperture and power 60×, with a fine wire micrometer. A darkened glass was varied to facilitate safe viewing. A Mr Gray had his observatory in the nearby Garstin's Buildings where he had an astronomical clock. Prinsep used this clock to calibrate his chronometer before and after the transit (Phillimore, 1958(4): 114; Prinsep, 1832: 408–411).

Calcutta was cloudy around the time when the transit was to commence, and the Sun set before the egress took place, defying any attempts to time all of the contacts and correct the longitude of the city. Still the clouds permitted occasional views of the event. A small spot was noticed on the Sun's disc that was indistinctly defined towards the advancing limb. Transit timings of this spot were noted down. The observers noted that the time taken by the passage of the planet of a wire was about half a second. They also took due notice of the effect of atmospheric refraction on the duration of the passage of the Sun's disc across the wires as the evening advanced. The planet's disc appeared circular, "… surrounded with a slightly enlightened ring." Prinsep tabulated the timings of Mercury's centre, of the sunspot and of the limbs of the Sun past the wires of the micrometer in Mean Solar Time for a Calcutta latitude of 22° 36′ 21″ and longitude of 5h 53m 28s. He also measured the distance from Mercury's centre to the tangent of the northern limb of the Sun with the micrometer.

Prinsep (1832: 411, 504–506) also summarised the observations of the transit made at Calcutta, Chupra and Barelly. At Calcutta, the observations were made at the Surveyor General's Office in Park Street but were affected by the state of weather.

Walter Ewer observed from Chupra (latitude 25° 43′ N, longitude 5h 39m E). He used a Troughton 3½ feet long achromat with an aperture of 2¾ inches, power ~60×, and noted the internal ingress of the planet as at 2h 42m 18s mean time.

H.S. Boulderson observed the transit from Barelly. He noted the internal ingress at 2h 20m 58s, Barelly mean time. However, he considered this observation inaccurate by 2 or 3 seconds since Mercury had just entered the Sun's disc when first seen. He had intended to use the transit observations made at Hull (53° 45′ 57″ N, 1′ 21″ W) in order to determine longitudes of a few places in India with a greater degree of certainty. However, he was concerned when the derived conjunction timings differed from those given in *Nautical Almanac* and the *Berlin Almanac* (Boulderson, 1833: 318–320). He compared the timings at Hull, Barelly, Chupra and Calcutta, and deduced the respective longitudes from Greenwich as Barelly: 5h 17m 40.78s, Chupra: 5h 39m 5.85s and Calcutta (Surveyor General's Office): 5h 53m 31.14s. For comparison, he also determined the longitude of Barelly on the basis of lunar occultations of stars and emersions of Jupiter's first satellite during October–December 1832.

Figure 15: A painting of James Prinsep in 1840, by his sister Emily Prinsep (Wikimedia Commons).

Henry Smith Boulderson (1800–1877) was the Magistrate at Bareilly, and at the time worked for the "… Hon. East India Company's Civil Service …" He was proficient in both Bengalee and Sanskrit. In 1837, he rose to be Commissioner of Revenue in the Meerut Division. He figured in *The East-India Register and Army List for 1845*, listed as Member, Sudder Revenue Board, Agra (Rootsweb, n.d.).

As assay master, James Prinsep had worked to reform the Indian weights and measures system and introduced uniform coinage. He was the founder, and editor of the *Journal of the Asiatic Society of Bengal* from 1832 to 1838. It was during this period that he deciphered the Brahmi script and the Kharosthi script in the Asokan edicts, thus opening a window to early Indian history. From the study of coins and inscriptions, Prinsep was able to deduce many royal genealogies. A collection of his Calcutta watercolour paintings was published as lithographs in England in the book *Benaras Illustrated, in a Series of Drawings* in 1831 (Prinsep, 1831) and earned him great fame. He was a Fellow of the Royal Society. There is a 'Prinsep Ghat' on the banks of the Hooghly River built in 1843 in his honour.

On page 2 in the 1832 *Madras Almanac* (published by Asylum Press) there is essential information about the 5 May transit of Mercury, stating that it would be visible from Madras:

	D.	H.	M.
External Ingress Mean Time	5	2	20
Internal Ingress	5	2	24
☿'s nearest approach to ☉	5	5	46
☉ Sets	5	6	12

Figure 16: An undated cropped photograph of N.R. Pogson (courtesy: Indian Institute of Astrophysics Archives, Bengaluru).

The transit was observed at Madras Observatory by Thomas Glanville Taylor (1804–1848). Taylor had succeeded John Goldingham as Director in 1830, the same year in which the Observatory acquired a 5-foot transit instrument, a 4-feet mural circle and a 5-foot equatorial telescope, all by Dollond. Once in office, Taylor lost no time installing these instruments (Kochhar, 1985b).

The introduction of these new instruments enabled work of greater astronomical relevance and precision to be carried out at the Observatory. As was the norm for British colonial observatories at this time, research at Madras Observatory focused on positional astronomy. The culmination of these early efforts by Taylor was the famous catalogue of 11,015 stars in the southern sky (Taylor, 1844). However, Solar System objects and events, and occultations of stars and planets by the Moon were also observed.

Taylor observed the 5 May transit of Mercury with the 5-feet Dollond achromat, using a power of 110×. Contact I was lost, but he did time the passage of the centre of the planet's disc and Contact II. High winds vibrated the telescope and prevented further observations (Taylor, 1835: 113). Here are the timings he was able to make:

	h.	m.	s. Mean Time
The Exterior contact at ingress was lost.			
Centre of Planet (by estimation) in contact with the Sun's limb	2	22	21.5
Interior contact at ingress	2	23	37.3

There is no specific comment on what the planet looked like, and whether the aureole—an off-centre bright spot on the black round disc of the planet—was visible, as seen by some observers of the transits in 1736, 1786, 1789, 1799, and also later, in 1868 (Huggins, 1868: 25–28).

There is a list of the "MADRAS Observations and papers from the East India Company's Observatory at Madras" among the Manuscripts from the period 1769–1850 in the possession of the Royal Astronomical Society (https://ras.ac.uk/library/about-the-library/mss-lassell-pigott accessed 21 July 2024) but there is no mention of any observations of the transits of Mercury of 1799, 1802, 1822 or 1832.

The transits of 1835 and 1845 were not favourably timed for observations from India. The next transit, in November 1848, was partially visible from India (it commenced late in the afternoon), but also was not observed. The next transit that was observed took place in 1861. Prior to this, in December 1848, W.S. Jacob (1813–1862) had succeeded Taylor as Director of Madras Observatory. He, in turn, was replaced by Norman R. Pogson (1829–1891; Dreyer, 1892; Figure 16), in February 1861. Pogson remained Director until his death on 23 June 1891.

8.4 Multiple Observations of the Transit of Mercury 11–12 November 1861

Figure 17 shows Madras Observatory in Nungambakkam as it appeared in 1860–1890. In *A Memoir on The Indian Surveys*, the noted geographer Sir Clements Markham (1878: 323–341) had this to say:

> 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 [Pogson] is engaged in the prosecution of labours which are of great importance to astronomical science.

Figure 17: Madras Observatory at Numgambakkam during the period 1860–1890 (courtesy: Indian Institute of Astrophysics Archives, Bengaluru).

Once settled in the job, Pogson commenced a series of astronomical observations. Apart from positional astronomy as the routine, he began his observations with the solar eclipse of 7 July 1861, the transit of Mercury of 11 November 1861, and a few other events. The transit is mentioned on page 7 of Pogson's hand-written report of Madras Observatory for the year 1861 bearing this out.

Pogson kept logbooks with details of the observations he made. However, he did not publish all of his observations in academic journals. His account of the 1861 transit is a case in point, even though he communicated his discovery of the new minor planet 'Asia' to the *Madras Journal of Literature and Science* on 10 June 1861 and to the *Journal of the Asiatic Society of Bengal* on 19 September 1861 (Pogson, 1862: 291–293).

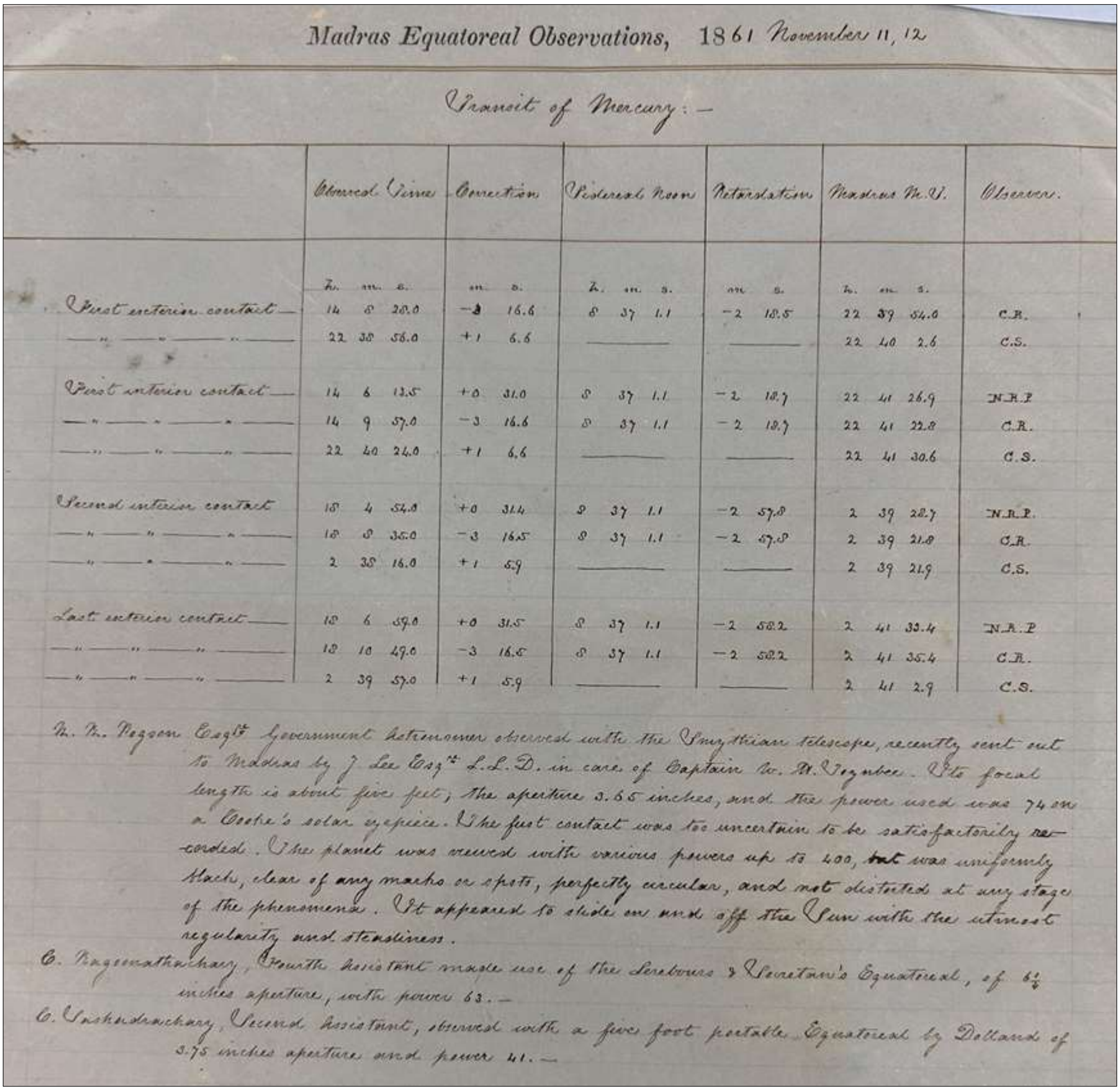
Courtesy of the IIA Archives, we have an image of the page in Figure 18 detailing the transit of Mercury of 11–12 November 1861. It was taken with a mobile phone with ambient lighting since no flash was permitted. The page is in Pogson's own hand-writing where he also names, at the bottom, the observers: C.R. (C. Ragoonathachary, Fourth Assistant), C.S. (C. Sashadrachary, Second Assistant) and N.R.P. (himself). CR used the Observatory's Lerebours & Secretan equatorial of 6¼ inches aperture with a power of 63×. CS observed with a 5-feet portable equatorial by Dollond of 3.75-inches aperture and a power of 41×. Pogson used the 5-feet Smythian telescope with an aperture of 3.65 inches and a power of 74×, which had been "… recently sent out to Madras by J. Lee Esq. L.L.D." Pogson noted all the contact times and corrections in Madras Mean Time. He says:

> The first contact was too uncertain to be satisfactorily recorded. The planet was viewed with various powers up to 400, but was uniformly black, clear of any marks or spots, perfectly circular, and not distorted at any stage of the phenomena. It appeared to slide on and off the Sun with the utmost regularity and steadiness.

The Madras New Almanac and Compendium of Intelligence for the Year 1861, included in the section "Eclipses of the Sun and Moon" the following details about the 1861 transit:

> A transit of Mercury over the Sun's disc November 11th–12th, visible at Madras.

	Madras Mean Time		
	d.	h	m
Ingress	11	22	37



Madras Equatoreal Observations, 1861 November 11, 12

Transit of Mercury: —

	Observed Time	Correction	Sidereal Noon	Interpolation	Madras M.T.	Observer.
	h. m. s.	m. s.	h. m. s.	m. s.	h. m. s.	
First exterior contact	14 8 20.0	−3 16.6	8 37 1.1	−2 18.5	22 39 54.0	C.R.
" " "	22 38 56.0	+1 6.6	———	———	22 40 2.6	C.S.
First interior contact	14 6 13.5	+0 31.0	8 37 1.1	−2 18.7	22 41 26.9	N.R.P.
" " "	14 9 57.0	−3 16.6	8 37 1.1	−2 18.7	22 41 22.8	C.R.
" " "	22 40 24.0	+1 6.6	———	———	22 41 30.6	C.S.
Second interior contact	18 4 54.0	+0 31.4	8 37 1.1	−2 57.8	2 39 28.7	N.R.P.
" " "	18 8 35.0	−3 16.5	8 37 1.1	−2 57.8	2 39 21.8	C.R.
" " "	2 38 16.0	+1 5.9	———	———	2 39 21.9	C.S.
Last exterior contact	18 6 59.0	+0 31.5	8 37 1.1	−2 58.2	2 41 33.4	N.R.P.
" " "	18 10 49.0	−3 16.5	8 37 1.1	−2 58.2	2 41 35.4	C.R.
" " "	2 39 57.0	+1 5.9	———	———	2 41 2.9	C.S.

N. R. Pogson Esq[re] Government Astronomer observed with the Smythian telescope, recently sent out to Madras by J. Lee Esq[re] L.L.D. in care of Captain W. H. Toynbee. Its focal length is about five feet; the aperture 3.65 inches, and the power used was 74 on a Cooke's solar eyepiece. The first contact was too uncertain to be satisfactorily recorded. The planet was viewed with various powers up to 400, but was uniformly black, clear of any marks or spots, perfectly circular, and not distorted at any stage of the phenomena. It appeared to slide on and off the Sun with the utmost regularity and steadiness.

C. Ragoonathachary, Fourth Assistant made use of the Lerebours & Secretan's Equatoreal, of 6¼ inches aperture, with power 63. —

C. Srinivasachary, Second Assistant, observed with a five foot portable Equatoreal by Dolland of 3.75 inches aperture and power 41. —

Figure 18: The Madras Observatory observation sheet completed by Pogson that gives contact timings of the transit, the observers involved and the equipment used (courtesy: Indian Institute of Astrophysics Archives, Bengaluru; photograph taken with a mobile phone by R.C. Kapoor).

Least distance of	12	0	39
Egress	12	2	39

Angle, from North Pole, of [First Contact, 71 towards the East] for direct [Last Contact, 24 towards the West] image.

The print of the *Almanac* in the Internet Archive's copy is not clear but the timings that can be read from it do match the observed ones, as shown in Figure 18. Interestingly, *The Ceylon Almanac and Annual Register for the Year of Our Lord 1861* also listed "The Transit of Mercury, November 12. Ingress 10h.35m., A.M., meantime at Colombo. Egress 2h.37m., P.M., meantime", under the heading PHENOMENA.

Pogson (1856) is known as the 'founder' of the modern definition of the logarithmic magnitude scale. While at Madras Observatory, he used the new 8-inch Cooke equatorial to discover five minor planets and seven variable stars, and re-discover the lost minor planet Freia. Pogson always had a large backlog of observations waiting to be reduced and published. The need for staff with knowledge of English, and financial constraints, forced him to employ members from his own family at the Observatory. Over the years, in his administrative reports Pogson credited a few observations to Elizabeth Isis Pogson, his daughter from his first marriage. Isis eventually became an Assistant Astronomer and Meteorological Reporter to the Government of Madras. Norman Pogson was the first to identify the presence of the new element helium, and the green line of 'coronium' (a forbidden line of iron) during the total solar eclipse of 1868 (Nath, 2013; Nath and Orchiston, 2021). In 1856 he was awarded the Lalande Medal by the French Academy of Sciences, and in 1860 he was elected a Fellow of the Royal Astronomical Society. Later, on 1 January 1878 he became a Companion of the Indian Empire (J.L.E.D., 1892).

There is nothing about the transit from two other Indian-based astronomy enthusiasts with telescopes. In Madras, Eyre B. Powell (1819–1904), a Cambridge Wrangler in Mathematics and a Fellow of the Royal Astronomical Society, was Principal of Presidency College. He had a small refractor, and he often observed astronomical objects and events, sometimes in collaboration with Captain W.S. Jacob, who was Astronomer at Madras Observatory between 1848 and 1858. Powell had published several papers in *Monthly Notices of the Royal Astronomical Society* on a range of topics, including double stars, comets and the enigmatic variable star *Eta Argus* (now Eta Carinae).

Similarly, there was nothing from the Reverend Dr. W.S. Mackay (1807–1865), who was a missionary at Chinsurah in Bengal. Only months before he had observed the Great Comet of 1861, computed its orbital elements and published these (Mackay, 1862). The Reverend was associated with the Bengal Mission of the Free Church of Scotland that was established in 1830.

The next transit of Mercury occurred in 1868, and this, too, was observed from India.

8.5 Nursing Row and the Transit of Mercury of 5 November 1868

Pogson's (1868) Madras Observatory Annual Report for 1868 places on record the expedition highlights of the Great Indian Eclipse of 18 August, the discovery of a new main belt asteroid he named Camilla on 17 November, and the recovery of asteroid Sylvia one week later, but there is no mention of the 5 November transit of Mercury. We checked Madras Observatory records in the IIA Archives, but there was no evidence that the transit was observed.

However, the transit was observed elsewhere in India by the amateur astronomer A.V. Narsinga Rao (1827–1892; Figure 19), with the Anglicized named of Nursing Row, or Nursingrow. Nursing Row observed from his home in Vizagapatam (Vishakhapatnam), and reported his observations to Charles Piazzi Smith (1819–1900). The communication appeared shortly after in the *Monthly Notices of the Royal Astronomical Society* (Nursing Row, 1869). Here is how Piazzi Smyth describes Nursing Row:

> The writer of the above extract is a Hindoo gentleman of Vizagapatam, whose family has been much given to science through two generations. He possesses an extensive Observatory, both astronomical and meteorological and is now about adding to the former a 6-inch Equatoreal, with driving clock, micrometer, and spectroscope; and to his library all the purchasable volumes of the *Monthly Notices of the Royal Astronomical Society*. (Nursing Row, 1869: 279).

As the above quotation indicates, Nursing Row inherited an interest in astronomy and an observatory from his father-in-law G.V. Juggarow (or Jagga Rao; 1817–1856), an affluent

Figure 19: A.V. Narsinga Rao (www.avncollege.ac.in/aboutus/history.html; accessed 4 March 2025).

zemindār (land lord), and pioneering Indian amateur astronomer (Kameswara Rao et al., 2011). In 1840 Juggarow had set up a private observatory (Figure 20) in Daba Gardens at Vizagapatam that was used for astronomy and meteorology. In the observatory was a Troughton transit circle and a chronometer, plus the optics for a 4.8-inch aperture f/14.2 W.S. Jones of London refractor. Using the achromatic objective, Nursing Rao created a complete telescope in his workshop. It had circles, levels and slow-motion controls, and an altazimuth mounting. He then used the telescope to observe the 18 August 1868 total solar eclipse and the November 1868 transit of Mercury. For more on the Nursing Rao and his father-in-law see Kameswara Rao et al., 2011; Kochhar and Orchiston, 2017: 732–736.

On 5 November, Nursing Row (1869: 278) made the following observations of the transit with his 4.8-inch telescope and he drew a diagram representing Mercury crossing the disc of

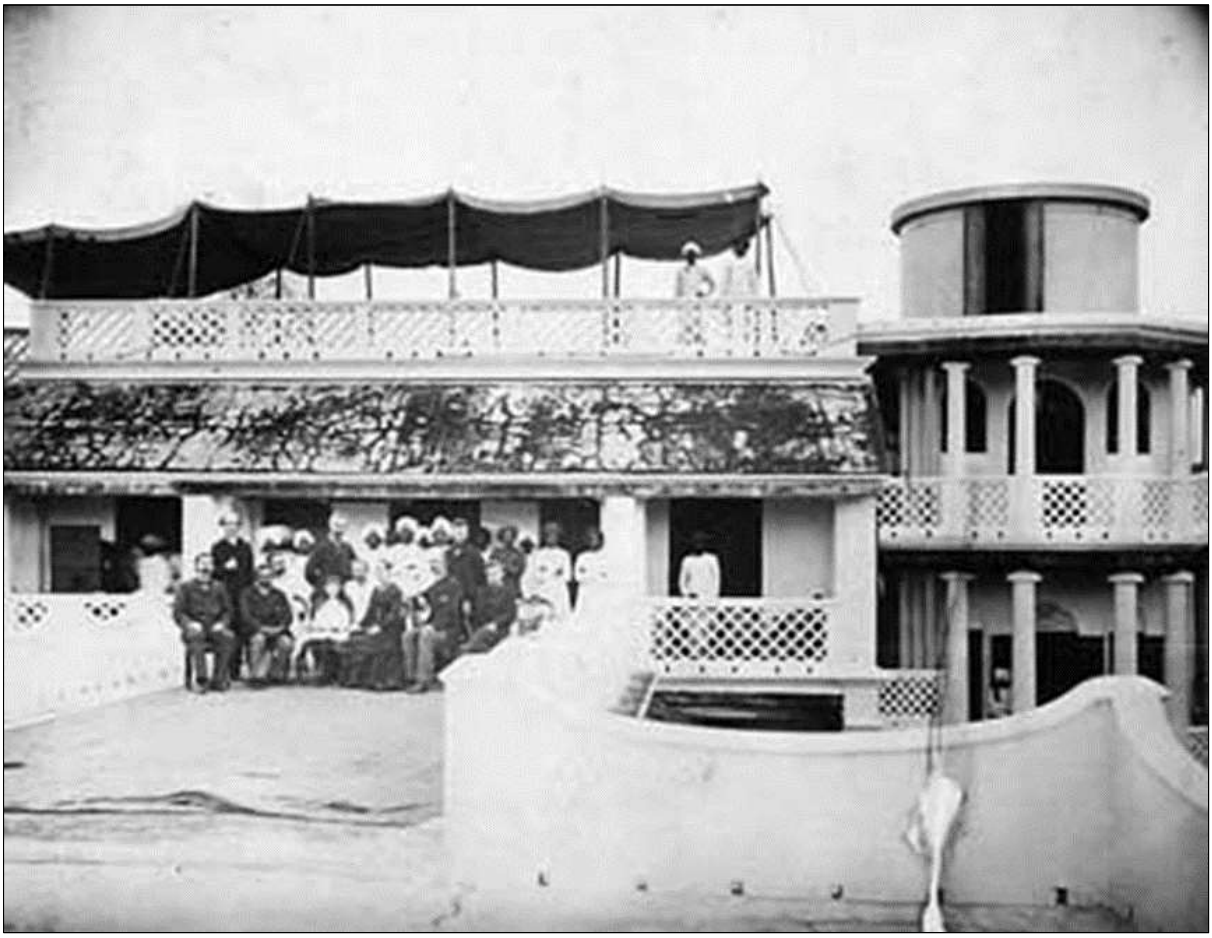


Figure 20: Nursing Row's Observatory at Daba Gardens, Vizagapatam (Visakhapatnam), showing European and Indian observers of the 9 December 1874 transit of Venus (courtesy: Royal Astronomical Society Library).

the Sun (Figure 21). He gave the contact timings as:

Mean Time	h	m	s
First contact	10	58	39
Last contact	2	35	57

Nursing Row (1869: 278) provided the following information about the transit:

> I have the pleasure to enclose herein a copy of a printed notice to friends in this neighbourhood, containing a rough diagram of the Transit of Mercury as it was seen here in Vizagapatam. The weather certainly favoured us on the 5th of November, and we enjoyed well the observation of the Transit. The planet was seen as an intensely dark spot on the Sun's disk. When the planet approached half-way of the transit, some of my European friends and myself observed a wavy tint of light darting from the upper edge, disturbed at times, but continued until the planet had passed some distance from the highest point of the line of transit. Suspecting it to be an effect of disturbed focus, I often refocussed the instrument and changed the eye-pieces, besides other precautions, yet we always observed the same phenomenon ...

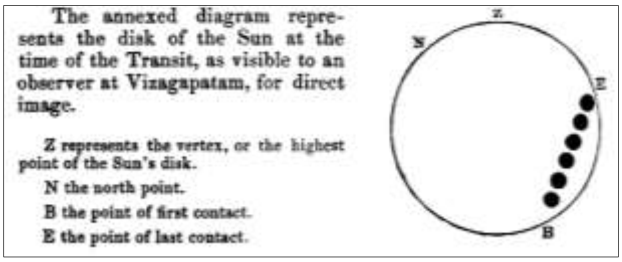


Figure 21: The diagram by Nursing Row showing the transit of Mercury (after Nursing Row, 1869: 278).

Over time, Nursing Row observed the solar eclipses of 12 December 1871, 6 June 1872 and 17 May 1882, the transits of Mercury of 8 November 1881 and 10 May 1891, and the 9 December 1874 transit of Venus 1874 at his Observatory (Nursing Row, 1875). Before the transit of Venus he replaced the modest Jones telescope with a 6-inch f/15 clock-driven equatorially mounted Cooke refractor.

Nursing Row's publications in *Monthly Notices of the Royal Astronomical Society* indicate a keen interest in astronomy and a zeal for knowledge. In 1871, the Government discontinued firing the time-gun on Dolphin's Nose near Vizagapatam, but Nursing Row came forward and maintained it at his own expense.

In 1871, Nursing Row was elected a Fellow of the Royal Astronomical Society and the following year of the Royal Geographical Society. Today the carpark of the Dolphin Hotel occupies the site of the observatory.

The next transit of Mercury was in 1878, but it was not favourably timed for India. However, the transit that followed, in 1881, was observable from India.

8.6 Nursing Row and the Transit of Mercury of 8 November 1881

Nursing Row used his 6-inch Cooke refractor to observe this transit. When the Sun rose, the transit was in progress, with the planet already half way across the disc. He computed the following timings (in Vizagapatam Mean Time):

	h	m	s
Middle of Transit	18	30	50
Internal contact at Egress	21	9	58
External contact at Egress	21	11	41

As with the previous transit of Mercury he send his results to C. Piazzi Smyth. The middle of the transit occurred at 6h 30m 50.4 a.m. with "… a least distance for the centres of 3′ 52″." It was around this time that the scene got more interesting, as described by Piazzi Smyth in Nursinga Row's (1882: 107) paper:

> But at this stage of the proceedings there came pouring into his Observatory such a stream of his English lady and gentlemen friends, that Mr. Nursinga Row confesses he rather lost his presence of mind as an observer. The egress of the planet was afterwards beheld; and found to agree closely with the time computed beforehand.

Meanwhile, for those living in Madras *The Asylum Press Almanac and Compendium of Intelligence 1881* contained essential information about the transit:

> A Transit of Mercury across the Sun's disc will be partly visible in India on the morning of Tuesday the 8th of November.
>
> For Madras

	h.	m.
Sun rises with Mercury upon his disc	5	58
Middle of Transit	6	18
Internal contact at Egress	8	57
External contact at Egress	8	59

> At middle of Transit Mercury will be 4′ South of the Sun's centre. The last contact occurs at 79° from the northernmost point of the Sun's limb towards the west. These phenomena will not be visible to the unaided sight, but can be readily seen with an ordinary telescope provided with dark glasses as usual for solar eclipses. (Moore, 1880: 10).

Madras observers missed it. Pogson's Report to the Chief Secretary to the Government dated 18 November 1882 (Pogson, 1882: 1) stated that the transit got clouded out.

The next transit of Mercury took place in 1891.

8.7 Multiple Observations of the Transit of Mercury of 9–10 May 1891

There are reports of observations of the May 1891 transit from Poona (Pune), Calcutta, Vizagapatam and Madras.

Figure 22: Kavasgee Dadabhai Naegamvala (after Kochhar and Narlikar, 1995: 17).

Professor Kavasgee Naegamvala (1857–1938; Figure 22) observed the transit on the morning of 10 May 1891 from the College of Science in Poona (Naegamvala, 1891a: 501–502). He used a 16½ inch Newtonian reflector, with the silvering removed from the primary mirror and a Pritchard's wedge interposed between the eye and the 130× Huyghenian eyepiece.

The Sun rose after the ingress had taken place, and the seeing was not exactly as desired since the Sun's disc appeared tremulous. Naegamvala found the disc of the planet circular, inky-black and darker than the brownish-black umbra of the large sun-spot on the solar disc. He did not notice any inner bright spot as most of the earlier observers had. However, he could see a circular aureole, with a thickness two-thirds of the planet's disc, brighter than the surrounding area with the intensity falling off at the margin. Naegamvala (*ibid*.) reported:

> The aureole was seen up to a very short time of the internal contact at egress, but I did not exactly note the time of its disappearance, as my attention was then directed more to the first formation of the bright ligament and black drop, if any. The bright ligament was sharply formed, and when just broken the planet's disc at once assumed a pear-like shape. Within two or three seconds, however, a very curious phenomenon was observed. A smaller pear (so to call it), about one-third the size of the other and of a lighter tint (i.e. less black), was seen to hang outside the limb of the Sun, the "pears" being attached together by their necks in one line. This lasted for about half a minute. The disc of the egressing planet next took the form of a half ellipse, with the semi-minor axis more or less radial; while just before external contact the disc assumed the form of a short and very flat dummy truncated cone with the apex towards the centre of the Sun. The height of the cone gradually grew less and less, till the planet was completely lost to view.

Professor Naegamvala had graduated with distinction from Elphinstone College, Bombay, in Physics and Chemistry in 1878, winning the Chancellor's Gold Medal (Kochhar and Orchiston, 2017: 749–752). He had joined the College as a Lecturer in Experimental Physics in 1882. Naegamvala specialized in spectroscopy and is rightly called India's first solar physicist, a talent acknowledged by Sir Norman Lockyer. Naegamvala came from a Parsi family of contractors. One may look up Ansari (2018) about his life and his work where, quoting from the Bombay archives, he has written about how the idea of establishing a spectroscopic laboratory at Elphinstone College developed. In 1882, Maharaja Raol Sir Takhtasingji Jaswantsinhji of Bhavnagar (1858–1896; r. 1870–1896) was on a visit to the University of Bombay when Naegamvala brought to his notice the lack of adequate means to pursue spectroscopy at the College and that he was ready to organize a laboratory to that effect if funding could be arranged. That motivated the Maharaja to offer a sum which was then matched by the Bombay Government. The only spectroscopic laboratory in India at that time was at St. Xavier's College in Calcutta (see Chinnici, 1995/96; Kochhar and Narlikar, 1995).

With support from Fr. Lafont, Naegamvala's interest turned to setting up an astrophysical observatory. To accomplish this, he obtained funding to visit laboratories and observatories in Europe to familiarize himself with the instrumentation that would be needed. At Sir Norman Lockyer's Solar Physics Observatory he trained to work with the new spectroscopic and photographic equipment. He drew up a list of instruments suitable for an observatory and even had it approved by the Astronomer Royal, Sir William Christie (Ansari, 2018: 177).

Naegamvala returned to Bombay and worked for some time in the spectroscopy laboratory at Elphinstone College. In 1888 he moved to The College of Science in Poona as Professor of Astrophysics. The College, founded in 1854 and re-named the College of Engineering in 1911, is the third oldest engineering college in Asia (www.coep.org.in).

The Maharaja Takhtasingji Observatory was established at Poona in 1888 by the Maharaja following Naegamvala's suggestion. It was equipped with the modern instruments, namely, a 16½-inch Grubb reflector, a 6-inch equatorial refractor by the Cooke, a 12-inch siderostat and solar grating spectroscope, a transit instrument, spectroscopes, photographic apparatus, a standard clock and a chronograph. The Grubb reflector was a Newtonian and, conspicuously, is missing from Glass' (1997) master list of Grubb telescopes. In 1897, the 16½ inch mirror was replaced by a 20-inch mirror by Common. This historic reflector is now known as the Bhavnagar Telescope and presently is at Kodaikanal Observatory. Its history has been explored by Kameswara Rao et al. (2014) who rightly call it "… the most widely travelled telescope in the country."

Naegamvala's notable observations included a spectroscopic study of the nebula in Orion, the May 1891 transit of Mercury, the spectrum of the great sunspot group of 1892, and photographing the nebula NGC 4594 (now known as the Sombrero Galaxy), etc. He also took spectra of Nova Persei soon after it was brought to his notice on 25 February 1901.

However, it was Naegamvala's observations of the total solar eclipse of 22 January 1898 that hold an important place in Indian solar physics. The path of totality passed over Maharashtra, Chhattisgarh, Jharkhand, Bihar and Nepal. Various expeditions were mounted and detailed accounts of the eclipse were reported by different groups from India, Europe, America and Japan. The College of Science in Poona established a camp at Jeur in the Sholapur district of Maharashtra, where Naegamvala as the team leader. His report gives full details of the eclipse and the expedition (Naegamvala, 1902).

Figure 23: A photograph of part of St. Xavier's College during the nineteenth century, including the Observatory where the 1891 transit of Mercury observations were made (courtesy: INAF-Osservatorio Astronomico di Palermo, Library).

Next to Naegamvala's (1891a) report dated 15 May on the 1891 transit of Mercury published in *Monthly Notices of the Royal Astronomical Society* appeared one by Fr A. de Penaranda, S.J. of St. Xavier's College Observatory, Calcutta (de Penaranda, 1891). It was actually a reprint of de Penaranda's newspaper report that Naegamvala (1891a: 502) chose to communicate to the *MNRAS* on 21 May, adding his own comment on the appearance of the planet as noted by himself and by de Penaranda. However, in his next communication of 29 July, de Penaranda gives a rejoinder to Naegamvala's description of the aureole. See below!

Founded in 1860, St. Xavier's College made a seminal contribution to the promotion of science and technical education in India. Beginning in 1875, the Belgian Father Eugene Lafont S.J. (1837–1908) worked to establish an astrophysical observatory at the College, which he had joined in 1865. Two years later (in 1867) he established a meteorological observatory. Lafont participated in Italian astronomer Pietro Tacchini's expedition to observe the 9 December 1874 transit of Venus from Madhupur in Bihar, which revealed the presence of water vapour in the atmosphere of Venus (Biswas, 1994; Kapoor, 2014). It was Tacchini who persuaded Lafont to establish an astrophysical observatory at the College and focus on solar astronomy. Figure 23 shows the Observatory in the late nineteenth century; later it was moved to a new site on the campus (see Orchiston and Kapoor, 2024).

In 1877, Lafont installed a 9-inch Steinheil equatorial telescope, a clock-driven Merz equatorial telescope with a 7-inch objective, 7-feet focus equipped with a Browning spectroscope, and a solar cœlostat (Udias, 2003). Because of their excellent optical and mechanical quality, Merz telescopes and other astronomical instruments were the favourites of observatories all over the world in the latter half of the nineteenth century (Chinnici, 2017).

Biswas (1994) has presented a detailed account of Lafont's scientific work at St. Xavier's College, and his contribution in founding the Indian Association for the Cultivation of Science in 1876 with Dr. Mahendralal Sarkar (1833–1904). At St. Xavier's College Lafont was joined in November 1874 by the mathematician and astronomer Fr Alphonse de Penaranda (1834–1896; Ghosh, 2019; Orchiston and Kapoor, 2024). Right up until his death in 1896 de Penaranda participated in the astronomical observations made by Lafont. These included the partial solar eclipse of 17 May 1882; the Mars–Saturn conjunction of 20 September 1889, the 17 June 1890 partial solar eclipse from Bhagal-

Table 3: Contact times for the 9–10 May 1891 transit of Mercury recorded at Madras Observatory (after Smith, 1891: 268).

Observer/Reference	Mrs. Pogson	Charles Michie Smith	*Nautical Almanac*
Time	h m s	h m s	h m s
Last Internal Contact		22 5 2	22 6 53
Last External Contact	22 9 42	22 9 28	22 11 48

pur, the transit of Mercury on 10 May 1891, and the lunar occultation of Jupiter on 6 October 1892. Some of the dates reported by Biswas (1994) are incorrect (and these were corrected above). The poet laureate Rabindranath Tagore (1861–1941) was introduced to science and astronomy in the early days by his father, but in his reminiscences he recalls his years at St. Xavier's College and fondly acknowledges the influence that de Penaranda had on him (Tagore, 1917: 109–110).

According to de Penaranda (1891: 503), the transit of Mercury of 9/10 May was well observed at St. Xavier's College Observatory as the weather turned out better than was usual around that time of the year. A team of three astronomers used the two telescopes to make direct and projected observations of the Sun. The ingress was not well observed and first external contact (at 5h 50m 03s) happened 57 seconds after the calculated time whereas at egress, the internal contact (10h 18m 49s) was 92 seconds before the calculated time. The external contact at egress could not be observed as by this time clouds had covered the Sun. Fr de Penaranda (*ibid*.) suggested that the timing discrepancies were possibly due to imperfections in the ephemeris of Mercury or a small excess in the adopted apparent diameter of the Sun, or both. The disc appeared purple-black whereas the spots looked brownish and "… less deep black." The aureole was seen and it had a yellow tinge. The team obtained good photographs of the event (but we could not locate any of these to reproduce in this paper).

Figure 24: Charles Michie Smith (courtesy: Indian Institute of Astrophysics Archives, Bengaluru).

The 9/10 May transit was also observed at Madras Observatory, just a few weeks before Norman Pogson passed away on 23 June 1891, and when he was already seriously ill. But not wanting to miss the event, he asked Charles Michie Smith (1854–1922; Figure 24) to observe the transit from Madras Observatory, who did so gladly (Smith, 1891). Smith used the 6¼-inch Lerebours & Secretan equatorial, power 102×, while Mrs. Edith Pogson had the Troughton and Simms 8-inch equatorial, and Pogson his old favourite, the 3.4-inch Smythian telescope from Hartwell House, with a 95× eyepiece. All three telescopes were provided with "… first-surface reflecting-prisms so as to render their full apertures available with moderately dark neutral tint eyepiece shades." (Smith, 1891: 269).

The morning was cloudy, the Sun appearing intermittently, but the sky became fairly clear during the last hour of the transit. Pogson and Michie Smith both noticed the central white spot but not the halo, as recorded elsewhere or in previous transits. Michie Smith examined the spectrum with a direct-vision spectroscope attached to the telescope and commented:

> The disc of Mercury formed a perfectly black band along the spectrum, and there was not the slightest trace of any thickening of the absorption-lines close to the planet … There was no sign of any ligament or black drop; but just before the last external contact the part of the planet still on the Sun's disk appeared like a black triangular notch, which seemed to disappear and reappear repeatedly before Mercury was clear of the Sun. (Smith, 1891: 268).

Taking down the egress timings was quite difficult because of the poor seeing but both turned out to be well before the times calculated from the reduction formulæ in the *Nautical Almanac*. The timings, reduced to the Madras Mean Time, are listed in Table 3. Smith noted that there were two large groups of sunspots on the solar disc and a small circular one, but this was distinct from Mercury as it had a noticeable penumbra.

Smith's communication to *The Observatory* dated 14 May 1891 elicited a comment from Naegamvala on the matter of the 'halo' not being seen by the Madras observers. In his communication dated 29 July to the same journal, Naegamvala (1891b: 310) affirmed that he could observe it by employing a Pritchard's wedge (Naegamvala, 1891a), adding that

> I feel confident that the Madras observers would not have failed to notice it if they had either changed the 'dark glasses' or employed a wedge.

The 'wedge', named after Charles Pritchard, is a sliding wedge of shaded glass placed between the eye and the eyepiece of a telescope (see Langley et al., 1886).

Nursingrow (1891) also states that he observed the transit of Mercury from his observatory at Daba Gardens in Vizagapatam. In his communication he supplied a schematic diagram representing the Sun in direct image as seen, marking the points of first and last internal contacts.

The Sun was clouded out until 6h 10m, but when it became visible, Mercury could be seen on the solar disc some distance from the limb. It looked like a small circular spot, but darker than the umbrae of the sunspots. Nursingrow (1891: 504–505) noted:

> We did not find a ring of faint light round the planet, neither did we see a wavy tint of light darting from the upper edge of its disc as we noticed during the transit of 1868, p. 278, vol. xxix., *Monthly Notices of the Royal Astronomical Society*, 1869. The telescope now used is a 6-inch refractor by Messrs. Cooke and Sons, equatorially mounted under a revolving dome.
>
> During the whole transit, the planet appeared as a circular dark spot on the Sun's disc. We did not observe that its contour became pear-shaped just before egress; but on reaching the edge of the Sun's disc, it formed a dent quite circular on the limb. This we took for internal contact at egress = $10^h\ 17^m\ 11^s1$ Vizagapatam mean time (civil reckoning). The planet's bisection was observed = at $10^h\ 19^m\ 38^s{\cdot}6$, and the external contact at egress at $10^h\ 22^m\ 6^s{\cdot}8$.

Mercury's next transit was in 1894, but this was not visible from India. The transit of 1907, on 14 November, was partially observable from India, but it commenced late in the afternoon. Evershed's (1908: 280) Annual Report for Kodaikanal Observatory does not mention it, but he does say that the weather was not favourable for observing in some months, including November. The next transit took place in 1914 and was observed from India (Anonymous, 1914).

9 ASTRONOMICAL OBSERVATORIES IN EARLY TWENTIETH-CENTURY INDIA

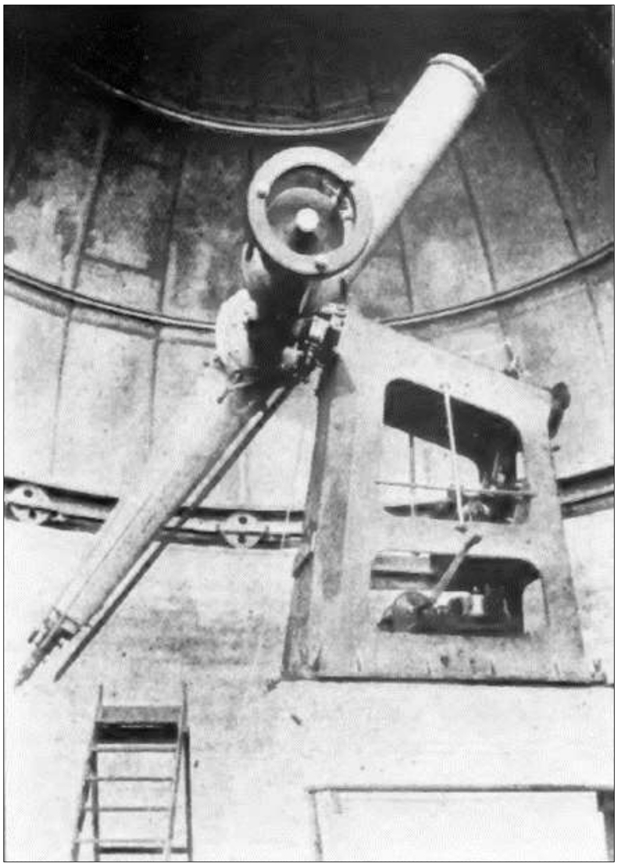
Madras Observatory existed as a scientific institution from 1792 to 1931, but in 1899 its solar activities were transferred to a new facility, Kodaikanal Observatory (see Figure 25). This was located in the Palani Hills to the south of Madras and inland from the coast, where there were better skies and there was room for future expansion. Charles Michie Smith served as Director of both Kodaikanal and Madras Observatories from 1891 to 1910. Noted British solar astronomer John Evershed (1864–1956) joined Kodaikanal Observatory on 21 January 1907 as Chief Assistant to the Director, and he served as Director from 1911 until 1923. Although the observations focused on solar physics, from time to time other celestial objects attracted attention.

Kodaikanal Observatory has now (as of 2025) been an active international solar astronomy research centre for more than 125 years. Since 1904, a spectroheliograph has been in operation, taking photographs of the Sun on every clear day in a narrow wavelength band centred around the K-line of ionized calcium (https://www.iiap.res.in/solar_images/). Meanwhile, Evershed was responsible for introducing a second spectroheliograph that worked at the wavelength of the Hα line. The original spectroheliograph provides information on the upper layers of the chromosphere of the Sun, while the Hα images help us learn more about the lower chromosphere.

The wealth of the photographic material collected at Kodaikanal Observatory has great archival value since it covers eleven consecutive sunspot cycles. Only the observatories at Meudon in Paris and on Mount Wilson in California have comparable records. The extensive Indian dataset provides a very good opportunity to study variations in solar activity and even the solar rotation rate over the past century or more (e.g. see Chatzistergos et al. (2019), Kharayat et al. (2024), Mandal et al. (2017) and references therein).

In 1901, a private observatory was established in Hyderabad through the efforts of an aristocrat Nawab Zafer Jung Shamsul Mulk Bahadur (Orchiston and Kapoor, 2023; Sanwal, 1983a: 1; 1983b). He had a small telescope and later bought another much larger one, a Grubb refracting telescope of 15-inches aperture (Figure 26), plus an 8-inch Cooke astrograph, clocks, and even meteorological instruments. The Nawab erected an observatory on his estate at Phisalbanda in Hyderabad. After the Nawab's demise in 1907, as he had wished, the Observatory was taken over by the Government of

Figure 25: "Painting of the Kodaikanal Observatory by an unknown artist (1908)." (courtesy: Indian Institute of Astrophysics Archives, Bengaluru).



India in 1908. The English astronomer Arthur B. Chatwood became its first Director.

The Nizamiah Observatory as it came to be called was moved soon to Begumpet, and the astrograph was installed by the end of 1909. In due course the Observatory joined the International Astrographic and Carte du Ciel projects to photographically map the sky down to magnitude 14 and record accurate positions for all stars down to magnitude 11. Eighteen observatories from around the world participated in these projects; Nizamiah was the only one from India, and used its 8-inch astrograph. Initially, the Observatory was allocated the region of the sky between the declinations of +17° and –23° and subsequently between +39° to +36°. Beginning in 1914, this project lasted until 1946, initially under A.B. Chatwood (Director 1908–1914; Orchiston, and Kapoor, 2023). Succeeding him were fellow-British amateur astronomer Robert J. Pocock (1914–1918) and the Indian scholar T.P. Bhaskaran (1918–1944). The result was 12 star catalogues, which included >442,000 stars (Sanwal, 1983a; 1983b).

Figure 26: The 15-inch Grubb telescope at Nizamiah Observatory (Bhaskaran, 1923: 499).

9.1 Nizamiah Observatory and the Transit of Mercury of 5 November 1914

The transit of Mercury in 1914 was visible from India. The 5 November issue of the journal *Nature* gave the contact timings, the planet's minimum separation from the centre of the Sun's disc and provided some useful tips for the prospective observers, suggesting how best to make observations, etc. (Anonymous, 1914):

> Next come the measurements for the determination of the diameter and the flattening of the planet's disc. Rings (aureoles) around the black disc of Mercury form interesting objects for observation and their intensity in relation to the neighbouring solar surface should be studied. A spectroscopic survey of these rings would decide whether their existence was real or not and the question of an atmosphere round Mercury could thus possibly be inquired into. Other points of interest relate to luminous appearances on the dark disc of the planet, possibility of satellites, occultations of solar spots, and faculae by the disc, etc.

The 7 November transit was observed in India at Nizamiah Observatory. R.J. Pocock (Figure 27) carried out the observations, and his report appeared in the November–December issue of the *Journal of the Astronomical Society of India*. The observers had planned to observe the first and second contacts with the finders of the 15-inch Grubb and the 8-inch Cooke astrograph. Pocock (1914: 33) reported that

> The first contact, however (always a difficult observation), was not observed and the 2nd contact was only observed with the finder of the 8-inch Cooke photo-visual, aperture 2½ inches. The observation was made by Mr. T.P. Bhaskaran Shastri, Assistant with a pocket chronometer belonging to the Director which was compared immediately after with the standard (Cooke) sidereal clock of the Observatory.

	h.	m.	s.
The observed Indian Standard time was–	15	29	36.81
The computed time	15	29	35.21
Difference			1.60

To compute the time of the second contact, he took the Observatory's geographical coordinates as +17° 19′ 20″ (latitude) and 5h 13m 37.66s E (longitude) that he said might be slightly in error since the same had never been accurately determined.

Figure 27: R.J. Pocock (after Sanwal, 1983a).

No report about the transit was issued by Kodaikanal Observatory

The next transit of Mercury visible from India took place in 1924.

9.2 Nizamiah Observatory and the Transit of Mercury of 7 May 1924

T.P. Bhaskaran (1889–1950; Figure 28) was the Officer-in-Charge of Nizamiah Observatory during 1918–1922 and was appointed Director in 1922 (Ali, 1951: 154). The 15-inch Grubb refractor was installed at the Observatory rather late, in 1922, under Bhaskaran's supervision. In 1939, the Observatory also acquired a Hale spectrohelioscope, in order to conduct solar observations in Hα. During Bhaskaran's tenure, in 1919, the Observatory was transferred to Osmania University, which had only been established in 1918.

The transit of Mercury of 7 May 1924 was observed from Nizamiah Observatory. In his report Bhaskaran (1924: 545) mentions good seeing conditions. The ingress had taken place 2½ hours before the Sun rose over Hyderabad so that only the last two contacts could be observed. Bhaskaran used the 15-inch Grubb with the aperture stopped down to 6 inches and

Figure 28: T.P. Bhaskaran (after Sanwal, 1983a).

a solar filter over the 150× eyepiece. A marine chronometer was used to determine the contact timings. The planet was observed through the telescope at frequent intervals, and found to be a black disc with a distinct edge. There was no luminous ring around the disc of the planet, but a persistent white spot was noticed at its centre. The timings of the egress were given, in G.M.T., as follows (*ibid.*):

Black drop began to form	17h 35m 41s
Geometrical contact (Internal)	17 35 56
External contact	17 38 16
	(probably too early)

The next transit of Mercury visible from India was in 1924.

Figure 29: The transit of Mercury of 8 May 1924, photographed at Kodaikanal Observatory at 10:25 IST (courtesy: Indian Institute of Astrophysics Archives, Bengaluru).

9.3 Kodaikanal Observatory and the Transit of Mercury of 8 May 1924

Thomas Royds (1884–1955), Director of Kodaikanal and Madras Observatories from 1923 to 1937, went on leave from 24 November 1924 to 17 December 1925, and his Assistant, A.A. Narayana Ayyar, was left in charge of the Observatory during that period. Ayyar prepared the Annual Report of the Observatory for 1924, but there is no mention of the 8 May 1924 transit of Mercury.

I therefore requested copies of solar images taken on the day of the transit, and found that three plates were exposed, at 08:12, 10:25 and 10:45 IST (IST = UT + 5:30). All showed Mercury on the disc of the Sun. The plate taken at 10:25 is presented here in Figure 29. It is a digital image of the original plate, which was taken with a 4k × 4k CCD camera. The vertical line is the E–W of the Earth. The planet can be seen near the top of the right hemisphere (West) in the image, implying that the exposure was taken near the end of the transit. For reference, the transit timings (UT) per Espenak (2016) are: 1st Contact: 21:44, 2nd Contact: 21:47, Greatest: 01:41, 3rd Contact: 05:35, 4th Contact: 05:38, Minimal Separation: 84.6″. The other two plates also clearly show Mercury, but at slightly different locations on the Sun's disc.

The Observatory used to publish *Kodaikanal Observatory Bulletins* (KOB) that contained almost daily records of the solar prominences observed, and occasionally other events. *KOB* issue LXXVI was all about the prominences observed during the first half of 1924, and although observations made on 8 May were listed there was no mention of the transit.

The next transit of Mercury that was visible from India occurred in 1927.

9.4 Multiple Observations of the Transit of Mercury of 10 November 1927

After 1924, Mercury passed across the Sun on 10 November 1927. The transit was observed at Kodaikanal Observatory following a request from R.T.A. Innes, the Union Astronomer in Johannesburg, South Africa (Royds, 1928a: 4), a former Sydney amateur astronomer (Orchiston, 2001; 2003; 2015). Innes (1928) stated in his Observatory's report for the year 1927 that Johannesburg was clouded out. Kodaikanal and Madras Observatories fared little better: only the second and third contacts, respectively, were observed. There is nothing more about the transit in the Annual Report (Royds, 1928a).

Volume LXXXIV of the *KOB* contains a summary of prominences observed during the second half of 1927 but after 9 November there is a gap until 13 November (Royds, 1928b: 169). This gap covers the date of the transit of Mercury, when the North–East Monsoon usually is active over Tamil Nadu.

However, I discovered that there are plates in the Observatory's collection that were taken on 10 November 1927, at 07:52 and 08:45 IST. Figure 30 is part of a digital image of the original plate of the full solar disc, taken with the 4k × 4k CCD camera. It shows the planet (the whitish circular patch) at lower right as at 08:45 IST (03:15 UT), implying that the exposure was taken near beginning of the transit. The transit timings (UT) as given in Espenak (2016) are: 1st Contact: 03:02, 2nd Contact: 03:04, Greatest: 05:46, 3rd Contact: 08:27, 4th Contact: 08:29, Minimum Separation: 128.7″.

The 10 November 1927 transit of Mercury was also photographed at Trivandrum Observ-

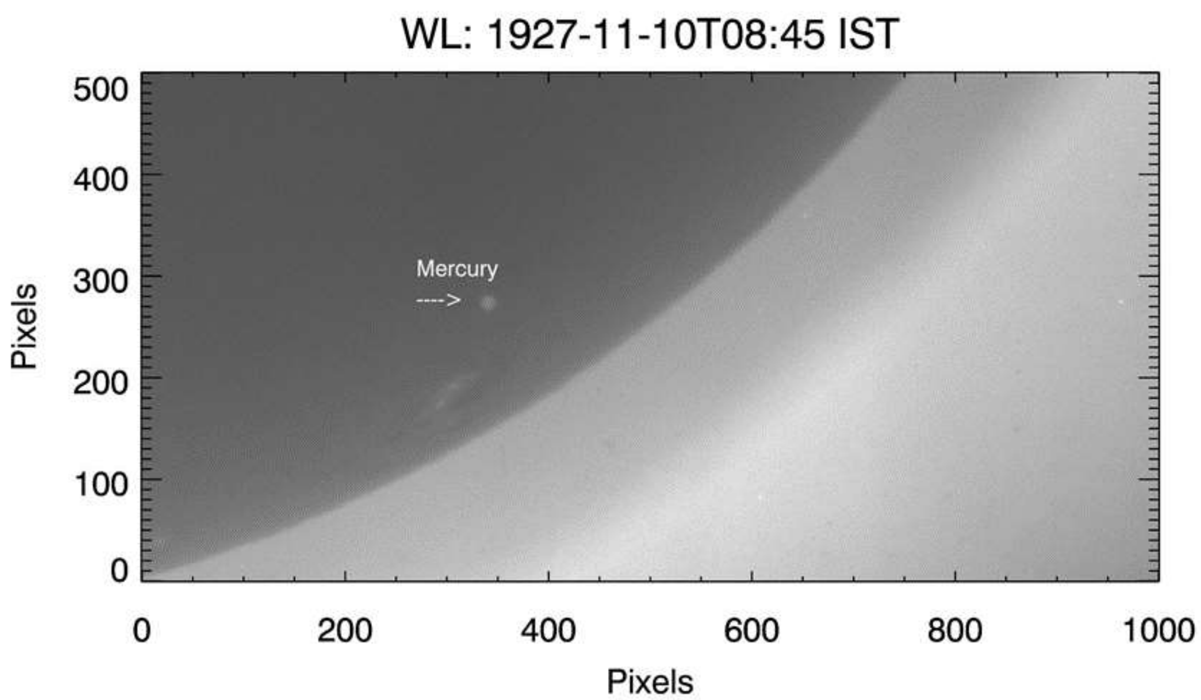


Figure 30: The 10 November 1927 transit of Mercury, photographed at Kodaikanal Solar Observatory, at 08:45 IST (courtesy: Indian Institute of Astrophysics Archives, Bengaluru).

atory according to Iyer's (1937: 45) report on the history of the Observatory. *The Travancore Almanac & Directory for 1927* included the following information for aspiring observers:

> A Transit of Mercury over the Sun's disc November 10. visible at Trivandrum
>
> Circumstances of the Transit.

	Hrs.	M	
First external contact	8	11.0	A.M.
Last "	1	37.8	P.M.
	Trivandrum Mean time		

Recall that Trivandrum Observatory was built in 1837 by Maharaja Swāthi Thirunal, and was very active in the 1840s (see Orchiston, 2025; Orchiston and Kapoor, 2023).

The Nizamiah Observatory report for the year 1927 (Bhaskaran, 1928: 283) mentions astrograph activity, the printing of the *Hyderabad Astrographic Catalogue* (Volume VI, Zone –22°), variable stars, lunar occultations, etc., but no transit of Mercury. However, it does mention that weather conditions were favourable for observing on only a few nights during the period June–November.

10 CONCLUDING REMARKS

The foregoing brings to an end our sequence of transits of Mercury observed from India. But the story is by no means exhaustive as there may be records as yet undiscovered. However, what is clear is that, with the turn of the twentieth century, the Indian astronomical community had lost interest in transits of Mercury. Before Independence in 1947, the last transit of Mercury observed from India was on 10 November 1927 (as described above).

While the transit of 11 May 1937 was visible from India, the 1937 Kodaikanal Observatory annual report does not mention it. Photographs of the Sun were taken that morning, but the transit commenced in the afternoon. The Nizamiah Observatory's 1937 Director's report only mentions observations of lunar occultations of stars (Director, 1938).

The transit of 11–12 November 1940 was partially observable in India, but it was an early morning event and even at the time of egress, the Sun was just ~15° above the horizon. However, no photographs of the transit were taken at Kodaikanal Observatory that day. Meanwhile, all of the solar images taken at the Observatory on 7 November 1941 were exposed before the transit began.

We need to accept that some of the pre-Independence transits of Mercury may have been lost to the North–East Monsoon, which was active over Southern India in October and November, and particularly over Tamil Nadu.

Since Independence, the following transits of Mercury have been observed at observatories in India: November 1953; May 1957, 1960 and 1970; November 1973, 1986, 1993 and 1999; May 2003; November 2006; May

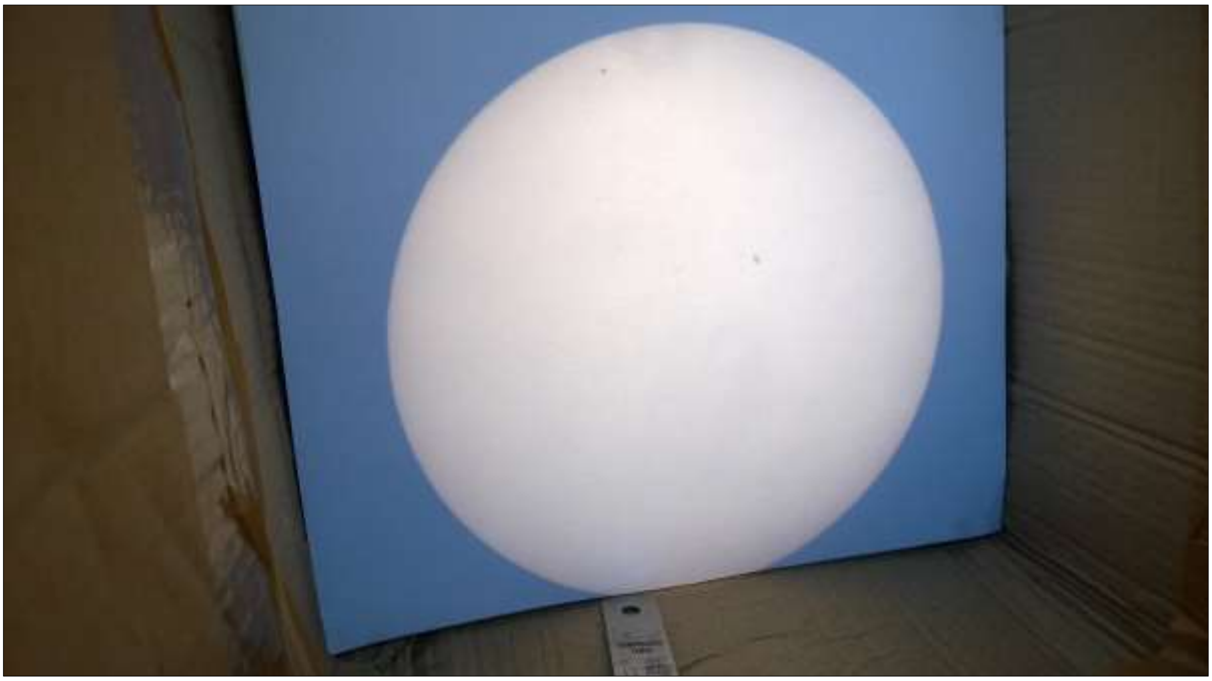


Figure 31: The 9 May 2016 transit of Mercury, with observed with a tripod-mounted 89/1400 mm Questar at the author's residence in Bengalaru. The ~9-inch diameter solar image shown here at 17:09 IST was projected onto a white board inside a carton that was fastened to a wall. Mercury is the small dot just left of top centre (photograph: R.C. Kapoor).

2016; and November 2019. Like other spectacular celestial events, increasingly these transits were used by observatories, educational institutions, astronomical groups and the media to create greater public awareness of astronomy.

As a young researcher, I was thrilled to witness my first transit of Mercury on 10 November 1973, at the Uttar Pradesh State Observatory (now ARIES), Nainital. At the time I worked there, researching flare stars. A pair of coelostats was used, and the solar image was projected onto a screen in a darkened room at the solar observatory. And there was Mercury, as a tiny black dot. The observation was for research, not for the public, although no publication followed and no pictures were available. That said, a logbook should be there to tell the story.

For the transits of 6 November 1993 and 7 May 2003, I used a 3-inch alt-azimuth refractor at the Indian Institute of Astrophysics in Bengaluru and projected the Sun's image for safe public viewing.

Figure 31 shows the transit of Mercury that occurred on 9 May 2016, as photographed from the author's residence in Bengaluru (GPS 12°.9317N, 77°.62489E) at 17:09 IST, 27 minutes after the first contact at 16:42 IST). Mercury is near the top of the solar image, but it was first noticed soon after first contact. The observations and associated explanation were arranged specifically for two young ladies, but the event was also observed by a few others and a section of the media. Their joy was indescribable, and obviously such events have great educational value.

To be able to successfully view a transit of Mercury a telescope equipped with filters is desirable. A magnification of 50× or more will give a nice view of the event. The method of projecting the Sun's image onto a screen in a darkened room is safe and has been used for centuries. During the transit, you should try to record the contact times, the ambient light conditions, and your location (using GPS). If you want to try photography use +5 ND filters.

The next transit of Mercury visible from India (weather permitting) will on 13 November 2032. Prepare for it, but remember:

DO NOT VIEW THE SUN DIRECTLY WITH THE NAKED EYE OR WITH A TELESCOPE.

11 NOTES

1. All translations in this paper from Latin and other languages into English were made by the author, unless otherwise stated.
2. Initially it was thought that the French Jesuit Fr. Jean Richaud (1633–1693) was the first to carry out telescopic astronomical observations from India, when he used a 12-ft telescope at Pondicherry (Kameswara Rao, 1984). In 19 December 1689 he discovered that α Centauri was a double star, making

this a significant milestone in the history of modern astronomy in India (*ibid.*). Richaud also observed a comet that same month (Louyat, 1982: 225–226), and is credited as its independent discoverer. He also determined the latitude and longitude of Pondicherry.

3. This comet must have been C/1652 Y1, which Shakerley first observed on 18 December 1652 (Gregorian date). Kronk (1999: 346–347) makes no mention of Shakerley, and awards the discovery to Jan van Riebeeck at the Cape of Good Hope on 16.8 December 1652. But in Kapoor (2018: 33–34) I promote Shakerley as an independent discoverer of this comet.
4. There are two Pavins listed in the *Asiatic Register* (1799: 172): John Pavin, 1st officer of the ship Upton Castle (operated by EIC in 1800) and Robert Pavin, a mariner. Both have maritime links, so we do not know which of these is the one referred to by Dinwiddie.

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The English translations of some original passages from texts in Latin and French cited in this paper were software-assisted, and were adopted after a few iterations.

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Professor Ramesh Kapoor completed a PhD at Agra University in 1980, but had begun his career as an observational astronomer in 1971 at the Uttar Pradesh State Observatory (now Aryabhatta Research Institute of Observational Sciences, ARIES) at Nainital. His main interest at that time was flare stars. From March 1974 until September 2010 he was with the Indian Institute of Astrophysics (IIA) in Bengaluru, where he worked on various topics in relativistic astrophysics: observational aspects of black holes, white holes, quasars, pulsars, etc. He has published in peer-reviewed journals and presented papers at national and international conferences.

He participated as an observer and organizer in IIA solar eclipse expeditions in 1980, 1983, 1995, 1999, 2009 and 2010; apart from Indonesia in 1983, all of these were in India. He also travelled to Columbia (South Carolina) to observe the eclipse of 2017 and to La Higuera (Chile) for the eclipse of 2019.

Ramesh's current interest is the history of astronomy in India. "Comet Tales from India", an ongoing project since 2009, seeks to record comets from the Indian region reported in publications, manuscripts and on inscriptions from antiquity until the nineteenth century where available data, however minimal, permit identification of the comet. The resulting research has been presented in journals and at conferences. His new project, "Eclipse Tales from India", seeks to trace total and annular solar eclipses mentioned in Indian written works or in inscriptions from antiquity until the nineteenth century.

All along, Ramesh has been active in promoting astronomy, with many popular articles published in national dailies and science magazines. He frequently interacts with the print and the electronic media on diverse scientific topics that are of interest to the general public. He has also published on Indian systems of medicine.

Ramesh has been a member of the International Astronomical Union since 1985; a Life Member of the Astronomical Society of India since 1973; an Associate of the National Institute of Advanced Studies (NIAS, IISc) since 2002; and a COSPAR Commission E Associate since 2005. His ORCID ID is https://orcid.org/0000-0002 4858-0476.

As reported on the title page of this paper, Professor Kapoor passed away unexpectedly on 21 August 2025, after having already submitted this paper to *JAHH*.