THE GROWTH OF MODERN ASTRONOMY IN INDIA, 1651-1960

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1. ANCIENT AND MEDIEVAL TIMES

India, as can be expected from an ancient culture, has a long astronomical tradition. The earliest interest in astronomy was in determining the four directions for ritualistic purposes, in making rather inexact calendars, and in observing stars near the zodiac as a guide to the motion of the sun and the moon. The development of mathematical astronomy in India came about as a result of interaction with Greece in the post-Alexandrian period. The leading figure in this modernization of Indian astronomy was Aryabhata I, who was born in AD 476 and completed his influential work, Aryabhatiya[1], in AD 499.

The main occupation of Indian astronomers for the next thousand years was the precise calculation of the planetary orbits and developing algorithms for the solution of the mathematical equations that arose in the process.

In the Indian scheme of things, there was hardly any place for observation. Stars were not studied, and observations were made only to the extent that they were required for carrying on planetary calculations. The instruments used were rather simple: a water- clock, a sundial, and an armillary sphere.

The indifference of the ancient Indians towards observation is tellingly illustrated by the pioneering Aryabhatiya itself. Theoretical planetary calculations require three empir- ical input parameters: earth's diameter, the distance to the moon, and the distance to the sun. There is no clue whatsoever in Aryabhata's work as to where he obtained these values.

Aryabhata takes the earth's diameter to be 1050 yojanas. It is not possible to compare this value with any other because yojana is not a standard length. (In fact, Aryabhata defined his own yojana so that 10 yojanas equal one arcminute of the moon's orbit). The distances to the sun and the moon, being in units of earth radii, can however be compared with others.

Aryabhata places the moon at 60½ earth radii and the sun at 875½ earth radii. These values are different from, and in fact less accurate than, the values of Hipparchus (d. ca. 125 BC) who devised the method of obtaining them from the simultaneous observation of solar eclipse from two stations on the same meridian.

Presumably Aryabhata obtained his values of these parameters from his own obser- vations of a solar eclipse.

Now, there is a strong tradition that Aryabhata's birth place Ashmaka was in what is now the south Indian state of Kerala. If this is true (not all scholars agree on this) then Aryabhata could have observed the total solar eclipse of AD 493 January 4, whose path passed through Kerala. Interestingly, Kerala has a legend that Aryabhata and his son Devarajan were excommunicated from their caste for the double sin of going to the sea and observing the eclipse. In any case the legend implies the existence of the practice of eclipse[2] observations.

It should be realized that Hindu astronomers treated astronomical results as revelations rather than deductions. The results were therefore preserved in the format used in the (divine) Rig Veda, that is as terse shlokas composed in the rigid framework of metre. In this format there was no place even for details of mathematical calculations or scientific arguments, let alone for observations that were in any case not considered to be important.

The introduction of the Arabs to astronomy came from translation of Indian texts. Given the formidability of these texts, which can only have been compounded in translation, it is probably not surprising that the Arabs decided to specialize in observational astronomy, rather than dabble in planetary calculations.

The first Indian astronomer in the Arab experimental mould was Mahendra Suri who in AD 1370 culled a small 32-star catalogue from Ptolemy's catalogue, and wrote a treatise on astrolabe, or yantraraja [3.]

In the early 18th century Raja Jai Singh set out to update the tables Ulugh Beg (1394- 1449) had prepared 300 years previously, in 1436. He built huge immovable masonry instruments which he himself had designed, on the pattern of brass instruments of the Arab-Persian school. Jai Singh built five observatories[3,4]: in 1724 at Delhi; in 1734 at his newly founded capital Jaipur; and later smaller ones at Mathura; Ujjain; and Varanasi (1737).

Before building these structures Jai Singh did experiment with brass instruments, but decided against them for a number of reasons: they were faulty, because of their mobility and size; the axes became worn and the instruments untrue; the graduations were too small for fine measurements, etc.

Obviously Jai Singh had no idea about the theory of errors, nor did he realize that small instruments have the great asset that they can be improved upon in the light of the user's experience.

In addition, unlike the case of France and England, there were no compelling reasons for him to use his not inconsiderable influence to develop technology to achieve the desired accuracy in metal. He then decided to build his observatories in the famous Indian tradition of palaces and temples. The very fact that he headed the observatory himself rather than offer full-time appointment to his 'assistant' Jagannath shows that for him it was a case of what we may call vijnan vilas (science as a royal pastime or diversion). To appreciate the term it must be remembered that it was customary for Rajas and Maharajas to give names like Raj vilas, Jai vilas or Lakshmi vilas to their palaces.

Ironically, Jai Singh's instruments are less accurate than Ulugh Beg's. Jai Singh's two quadrants (in samrat yantra, i.e., equal-hour sun dial) are of radius 49.5 ft(at Delhi) and 49 ft 10 in. (at Jaipur) whereas Ulugh Beg's sextant had a radius of 132 ft. Ulugh Beg could achieve a precision of 2-4 arcseconds, whereas Jai Singh's accuracy is of the order of a couple of areminutes[3,4].

Thus with all his enthusiasm and personal efforts Jai Singh remains a historical anachronism. Intellectually he belonged to the long-past medieval astronomical tradition even though chronologically he lived in the modern age of astronomy.

2. USE OF THE TELESCOPE IN THE 17TH CENTURY

It is interesting to note that telescopes were used from India in the 17th century itself. The earliest use appears to have been in 1651, barely 40 years after its use by Galileo. Jeremiah Shakerley (1626 - ca 1655), known in English astronomical circles[5] as one of the earliest followers of Kepler, emigrated to Surat in west India. He observed the 1651 transit of Mercury, but could time neither the ingress nor egress. His effort thus remains a historical curiosity[6]. Shakerley also observed a comet in 1652.

In 1689, Father Jean Richaud, a French Jesuit priest made astronomical observations from Pondicherry in south India, and discovered the binary nature of the bright star Alpha Centauri. In fact, the visiting Jesuit priests were the earlist users of the telescope ill India for geographical purposes, although their observations were not made use of till there arose colonial compulsions to learn about India's geography.

In the early 18th century, Raja Jai Singh himself owned a telescope, but apparently it was not of much use to him.

These telescopic swallows however did not make an Indian astronomical summer.

3. ADVENT OF MODERN ASTRONOMY IN THE 18TH CENTURY

Modern astronomy could take root in India only in the later half of the 18th century, when it was pressed into service as a geographical aid.

As the British East India Company's non-trading activities increased and it came to control more and more territory, many of its officers started making for their own amusement astronomical observations for the determination of latitudes and longitudes. Surveying instruments were thus in great demand. They could be purchased from England or from the captains and crew of the European ships. When an officer died or left the country, his surveying instruments would find ready buyers. In the early days, it was not the policy of the Company to supply surveying instruments to its officers. But a small stock of surveying instruments - sextants, quadrants, theodolites, clocks telescopes etc. was gradually built up by purchases from England or from within the country[7]

The transits of Venus in 1761 and 1769 saw a flurry of astronomical activity. At the request of the Royal Society of London, the company sent out reflecting telescopes, clocks, and astronomical quadrants for the observation of the 1769 transit from various places. The King of France deputed Guillaume Le Gentil (1725-1792) to observe from Pondicherry the transits of 1761 and 1769. He could observe neither, but spent the time determining the longitude of Pondicherry with respect to Greenwich and Paris.

An early British observer was the Calcutta-based Colonel Thomas Dean Pearse (1741/2 - 1789) who made observations of longitude and latitude from 1774 to 1779. He participated in the 1781-84 Mysore war and made observations on his march to and from Madras[7,8]. He used a clock by Ellicot; and a number of instruments: (i) transit instrument by Jonathan Sisson; (ii) a 'tolerably good' Hadley's quadrant and quicksilver, replaced in 1776 December by (iii) Ramsden's inverting land quadrant with a micrometer; (iv) Hadley's wooden octant and quicksilver (used in 1782); (v) A 15 inches radius land quadrant by B.Martin, belonging to the Company. It had been used by William Hirst during the 1761 transit of Venus; (vi) An 18 inches focus reflector by Gregory, with a brass stand, replaced in 1777 by (vii) a triple-glass Dollond refractor with a double-glass micrometer.

The early observers had to employ a lot of ingenuity. Pearse[9] modified Hadley's wooden octant so that he could take angles of 150° and consequently meridian altitudes as far as 75°. Similarly he modified the Dollond refractor: 'And I made a polar axis for it of brass with rack work, and a declination circle not divided, which also is racked; to which when the micrometer was used, the telescope was fixed'.

In 1787, the Company purchased the following instruments for survey work[7] in Bengal by Reuben Burrow (1747-92) one time assistant to the Astronomer Royal Nevil Maskelyne:

Arnold's chronometer	Sicca Rs 1000;

Astronomical quadrant	Rs 200;
Dollond's achromatic telescope	Rs 360.

A sicca rupee was a new rupee; after two or three years of use, it was at a small discount.

Burrow's 1789 proposal for an astronomical observatory was brusquely turned down by the Company[7] , so that individual efforts at Calcutta did not have any cumulative effect. In contrast, Madras turned out to be more congenial for matters scientific, thanks to the practical requirements there.

4. MADRAS OBSERVATORY (1786-1899)

In the 1780s the East India Company was already a big landlord on the east coast of India. Its geographical and navigational needs now came to the fore: (i) To survey the territories it already had; (ii) to increase revenue earnings; (iii) to ensure safety of sea passages; and (iv) to learn about the geography of the country the British were increasingly getting involved with. Astronomy was thus required for navigational and geographical purposes. As the sea traffic increased, the limitations of the Coromandel coast became abundantly clear. The Bay of Bengal is affected by monsoons for seven months in the year. Company ships that took barely six days between Calcutta and Madras in the winter months December - April could require 4-6 weeks at other times.

In addition, or perhaps as a consequence, the Coromandel coast is rocky, full of shoals, and without safe landing for the Indiamen, which therefore were often wrecked.

A survey of the coast was thus literally a matter of life and death, and eventually in 1785 a trained surveyor-astronomer, Michael Topping (1747-96), was sent out from England, passage paid, and equipped with surveying instruments[10]. He has been called[7] 'the most talented and highly qualified all round surveyor that served the East India Company during the 18th century'.

This is the place to introduce another character in the story, who along with Topping, was responsible for the establishment of a public observatory at Madras, the first one outside Europe. William Petrie joined the civil service[11] on arrival at Madras on 1765 June 25. Starting at the lowest rung as a writer (or a clerk), he rose to become a senior merchant in 1776. He served in the Governor's Council many times during 1790 - 1800 (the dates are variously given). Petrie officiated as the Governor for a short period from 1807 September until December. He left India in 1812 to take over as the Governor of Prince of Wales Island (Penang, Malaysia) where he died on 1816 October 27.

Petrie was not only an influential civil servant but enlightened also. He was himself an astronomer, and in 1799 ehthusiastically supported Major Lambton's proposal for a trigonometrical survey of peninsular India. Not much is known about the personal life of Petrie; his mother Margaret was the daughter of Andrew Waugh of Selkirk (Ref 7, Vol IV, p.473)

In 1786 November Topping set out by land on his survey of the coast north of Madras, and returned the next February[12] In 1786 itself Petrie set up an iron-and-timber observatory[13] at his 11-acre residence at Egmore, Madras, and furnished it with his own instruments. The next year, he hired a Danish youth John Goldingham (later FRS, d. 1849)as his assistant.

Petrie's observatory fulfilled the long-felt need for a reference meridian in British India and immediately became India's Greenwich.

In 1788 January when Topping was sent on the coastal survey south of Madras, he arranged for Petrie's observatory to be occupied in public service. Goldingham was now hired at a monthly salary of 15 pagodas (as against Topping's 192) to make observations of Jupiter's satellites at Madras corresponding to Topping's field observations[7]. [1 gold pagoda = 3½ rupees = 8 shillings].

When in 1789, Petrie left for England on a short visit he placed the Observatory in Topping's charge, offering it as a gift to the Government. Being made of iron and timber it could be removed and rebuilt.

Topping, backed by Petrie himself, made a strong plea to the government for nationalization of this observatory, pointing out' 'it is doubtless from considerations of this nature that the Hon'ble Court [of Directors] have come to the resolution of thus affording their support to a science to which they are indebted for the sovereignty of a rich and extensive empire'.

On 1790 May 19 the Court of Directors decided to accept Petrie's offer and to establish an observatory for[7] 'promoting the knowledge of Astronomy, Geography and Navigation in India'.

In 1791 a garden house was purchased at Nungambakkam, Madras, while the instruments were removed to the Fort because of the war against Tipu, Sultan of Mysore. The old garden house was provided with another storey, to act as the library, Astronomer's residence, and offices. A separate 20 ft x 40 ft single room was constructed in 1792 as the Observatory. This is an appropriate place to clear a misconception that has persisted for about 120 years. Topping prepared a description of the Observatory and sent two signed copies to London (they can be seen at the India Office Library and Records, and at Royal Astronomical Society.)[14]

An unsigned copy remained at Madras, and was prefixed to Goldingham's 1793 observations. (It is now at Bangalore[15], with the first several pages gone and the remaining near total destruction). Without caring to look for corroboration, Madras Astronomer Norman Robert Pogson as well as his successor Charles Michie Smith both assumed Gold- ingham to be its author and made him the first Astronomer and 1792 the year of the observatory's establishment[16] Writing in 1892 on the occasion of the 'centenary' of the Observatory Michie Smith wondered how Michael Topping's name came to be etched on the granite pillar in the Observatory. His version of the Observatory's history received wide currency[17] and has persisted to this day, notwithstanding the correct picture in two government-sponsored but poorly circulated books: Love's Vestiges of Old Madras', and Phillimore's Historical Records of Survey of India[7].

Instruments

In contrast to the Greenwich Observatory, which came into existence without any instruments, Madras had instruments but no observatory. 'The Company had from time to time Sent many valuable Astronomical Instruments to Madras, most of which, for want of a proper deposit, and of proper person to render them Serviceable, had been Scattered abroad in different parts of the Country, or lain by neglected at the Presidency'[14]. Topping collected these instruments at the Madras Observatory, whose starting point was Petrie's own instruments:

i A transit instrument by Stancliffe[18] - 'small but invaluable' — of exquisite workman ship -', and although its Axis is only Sixteen Inches and a half in length [it] has been adjusted in Mr Petrie's Observatory — to within half a Second of time at every altitude of the Meridian.'[14]

ii. Transit clock by Shelton[18] Similar to the one used by Capt James Cook in his transit of Venus expedition, it has been at Kodaikanal since 1899 and in use[19].

iii. A one-ft diameter quadrant by John Bird[18].

In 1793 the Company purchased the following for Madras Observatory[17].

iv. A circular astronomical instrument of 16 in. diameter by Troughton.

v. Six telescopes in Brass mounting with Racks and Hook joints for observing the Satellites of Jupiter - by Dollond. Two were retained at the Observatory, and rest distributed.

Topping also asked for six sextants of Mr Hadley's construction, made either by Ramsden or Stancliffe, according to his own modifications. These were not sanctioned[20].

The instruments collected at the Observatory under Topping included[21].

vi. Astronomical quadrant by Martin.

vii. Astronomical clock by Monk.

viii. Pocket chronometers in silver cases by Arnold, Nos 378, 391, 393, 397.

ix. In 1804 the Observatory acquired a portable transit by Ramsden. It came as a gift from John Goldingham who was proceeding on a long leave.

x. In 1808 the Observatory purchased an 'excellent' 18 in. circular instrument by Cary, from Lt-Col.John Munroe. This was in 1823 transferred for use by Sir George Everest at the Great Trigonometrical Survey of India (see section 5).

It was quite common in those early days for surveyors to borrow instruments from the Observatory or leave them there when no longer required by them.

Till 1830 the Observatory was wholly engaged in survey oriented astronomy. Its chief assets were the 20 in. transit and the 12 in. altazimuth 'neither of them bearing an object glass of so much as an inch and a half in aperture'.[22] The ever-expanding British colonial interests depended upon safe navigation, which in turn required familiarity with the southern skies. In 1826 state-of-the-art instruments were ordered. Whatever new instruments the Observatory acquired in the remainder of the 19th century came in the next four decades.[23] They are described below:

i. A 5 ft focus transit instrument and 4 ft diameter mural circle by Dollond[24] (1829), both with 3¾1 in. aperture telescopes. The instruments were ordered in 1826, received in 1829, and installed by Thomas Glanville Taylor (1804-48) in 1830. Taylor used these instruments during 1831-1843 to prepare his famed Madras catalogue of 11015 stars, which in 1854 was described by the

Astronomer Royal Sir George Airy as 'the greatest catalogue of modern times'.[25] The catalogue was revised in 1901 by Dr A.M.W.Downing, Superintendent of the Nautical Almanac, with financial assistance from the India Office and the Royal Society.

In February 1861, the object glass of the mural circle was reported stolen. Both these instruments were cut up and made into two handy telescopes for use during the 1868 eclipse.

ii. Three inch aperture telescope by Dollond[23] (1829)

Along with the transit and the mural circle was received a 3 in. aperture, 5 ft focus achromatic Dollond telescope mounted on a mahogany frame armed with brass, supplied with two graduated circles and a long axis moving on a graduated arc.

iii. Six inch equatorial by Lerebours & Secretan[25] (1850)

It came to Madras in 1850 as the personal property of Capt. William Stephan Jacob (1813-62) who installed it for reasons of economy on stout wooden trestles under a folding (rather than rotating) teak wood roof, atop the astronomer's residence. It was subsequently paid for by the Company (£500).

This telescope with an English mounting was made by M.Secretan at Paris, where Jacob's friend Charles Piazzi Smith inspected it and drew a sketch, which is now at the Royal Observatory, Edinburgh.[26]

Its defective objective was replaced in 1852 by the maker with a new one of 6 in. aperture and 88 in. focus. Using it Jacob showed in 1852 that the recently discovered crepe ring of Saturn was translucent. The discovery was independently made by William Lassel at Malta using a 20 in. reflector. This provided convincing proof that the rings of Saturn were after all not solid. In 1861, Pogson discovered his first minor planet with it, aptly naming it Asia.[27]

The telescope was remodelled in 1898 by Sir Howard Grubb of Dublin, who provided it with an electric drive and mounted a 5 in. aperture Grubb photographic lens on the equatorial.[28]

The telescope has been at Kodaikanal since 1899, and in use as a photoheliograph since 1912.

iv. Transit circle by Troughton & Simms [27] (1857)

With an objective of 5 in. aperture and a divided circle of 42 in. diameter, it was similar to but smaller than Airy's 1850 Greenwich circle, but 'divided by the same exquisite machinery'.[27]

It was ordered in 1855 and was constructed in 1857 under the supervision of Richard C.Carrington who had got a smaller one made in 1852 and who 'advised such alterations as his own instrument had led him to consider advisable'. The transit circle was received only in 1858, the delay in arrival being due to the 1857 turmoil in India variously referred to as 'the mutiny' or 'a war of independence'.

Either the instrument arrived without a set of instructions or they were lost. In any case, there were difficulties in its installation which could take place only in 1862 after an expert mechanic (F.Doderet) became available.

The transit circle was in use for 25 years (1862-1887)under the supervision of Pogson, who did not reduce most of the data. (These results were later published by Pogson's successor Charles Michie Smith). The damaged instrument is now at Bangalore.

v. Universal equatorial by Troughton & Simms[27] (1862)

This portable equatorial could be used with either of the two telescopes of apertures 2 and 2 ¾ in. It was formerly the property of Lt-Gen.William Cullen (1785-1862) British Resident of the State of Travancore since 1840, and was purchased on his death by Pogson for his planned southern sky survey on the lines of Argelander's Bonn survey; but this never materialized, thanks to the overbearing attitude of the Astronomer Royal. (The equatorial is now kept at Bangalore, with the two telescopes missing)

vi. Eight inch equatorial by Troughton & Simms (1864)[27]

The lens was made by George Merz, Fraunhofer's assistant and successor at Munich, and tested by the Astronomer Royal. Similar to a telescope made for the Liverpool City Observatory, it was ordered in 1861; made by Mr William Simms (cost Rs 5200); received in 1864; and installed two years later. In 1931 it was sent to Kodaikanal, where it was not set up till 1960 when its original mount was discarded (and probably lost) and another one used.

Maintenance

Madras Observatory did not get any new instruments after 1864. Its survival how- ever was ensured when in 1861 September, a German mathematical instrument maker, F.Doderet, was appointed at Madras to start workshops for the repair of levels, theodo- lites, etc. for the Public Works Department. In the mean time Capt. (later Lt-Gen.) James Francis Tennant (1829-1915), who was the director for a year from 1859 October to 1860 September (later the President of the Royal Astronomical Society), had purchased for the Observatory an excellent lathe, by Holtzaffel. With it and other tools from the arsenal, a workshop was set up at the Observatory, whose first task was the commissioning of the transit circle. Doderet looked after the instruments, improvised them, and made new ones out of those discarded. He kept the two equatorials - the observatory's lifelines - in working condition, years after they were no longer new. For the 1868 eclipse, Doderet made handy telescopes out of the parts of the historical 1830 transit and mural circle, thus proving that history is a luxury poorly-equipped observatories can ill afford.

The period 1830-64 can truly be called the golden age of the Madras Observatory. It was never so well endowed, before or after. It was because of the infrastructural support available that the Observatory could see the 19th century through, otherwise it would have met the fate of the observatories at Lucknow and Trivandrum (see sections 6 and 7).

THE GREAT TRIGONOMETRICAL SURVEY OF INDIA [7,8,36] (1800)

In 1799 with the fall of Tipu Sultan of Mysore the East India Company acquired vast territory in south India. Its control now extended from the east coast to the west. Immediately, Brigade-Major William Lambton, vigorously supported by his commanding officer Sir Arthur Wellesley (later Duke of Wellington), submitted a proposal to the Madras Governor Lord Clive suggesting a trigonometrical survey of the southern peninsula on the lines of ones recently conducted in France and Britain. The proposal was supported by the Governor's councilor Petrie, who had earlier been instrumental in the establishment of Madras Observatory.

The formal orders for the start of the survey were issued on 1800 February 6. The early assistants to Lambton were Lt John Warren of the 33rd Foot and Ensign Henry Kater of the 12th Foot (later FRS).

On 1818 January 1, the survey was extended to cover the whole of the subcontinent. It was named the Great Trigonometrical Survey of India (GTS) and placed under the direct control of the Governor General, with Lt George Everest (1790-1866) of Bengal Artillery as the chief assistant to Lambton, the first Superintendent of the Survey. Lambton died in 1823 and was succeeded by Everest who retired in 1843. The trigonometrical survey was a monumental scientific endeavour, unparallelled in the world by virtue of its vastness and problems of logistics.

Lambton started his survey with second-hand instruments[7]: a zenith sector with an arc of 5 ft radius made by Ramsden in 1791 or 1792; and a 16 in. circular transit instrument by Troughton. These instruments were part of a set sent to China as a gift that was refused. The Madras Government bought these (and other minor instruments) from Dr James Dinwiddie (d.l815) a lecturer of science at Calcutta, paying him Rs 3600. Lambton found them in 'a wretched state' and had to put them in working order.

In the early years, the surveyors had to get their own instruments. They, as well as the Survey, bought instruments from private individuals who had obtained them from England for astronomical purposes. Thus the Survey acquired a few altazimuths with circles of 15 to 24 in. diameter. Hasty disposal of instruments after Lambton's death left the GTS without any worthwhile instruments. Everest then obtained in 1823 an 18 in. altazimuth by Cary from Madras Observatory, which had purchased it second-hand in 1808. For this transfer, Everest took the help of Sir Charles Metcalf, Resident at Hyderabad who 'kindly obtained it for me from the Madras Observatory by his intercessions with Sir Thomas Munro [Madras Governor]'[36].It was used, after modifications, till 1846.

Whenever repairs were required, the survey officers had to carry them out themselves with the help of local mechanics at the Company ordnance depots. This was because sending the instruments to England via the Cape of Good Hope would be a matter of years with the added risk of loss of the ships. Thus in 1808 when the great theodolite was damaged in a fall at Tanjore, Lambton brought it to Bangalore, and repaired it himself, after 6 weeks of hard labour.

There was yet another problem. The instruments procured second-hand in India were astronomical instruments and not really suitable for survey work. The Madras 18 in. altazimuth was called excellent by the Astronomer, but the Surveyor General while referring to its use was less than enthusiastic, describing it as an instrument 'of very inferior powers, but such is the paucity of instrumental means' that there was no other resource to fall back upon[36]

Instrument Department

In 1830 the survey got some new instruments and more importantly a repair workshop. When Everest returned from England after a five year stint, he brought with him Mr Henry Barrow (1790/1 - 1870, later FRS) who had earlier done jobs for Troughton, Dollond, Jones, Walkins, etc. (Everest was introduced to Barrow by an assistant at Greenwich Observatory, William Richardson, who had refused an appointment at Madras which then went to his colleague Thomas Glanville Taylor). Barrow was appointed as the Mathematical Instrument Maker to the East India Company at a monthly salary of Rs.500 plus house rent; and a workshop was set up for him at Calcutta. (It is now known as the National Instrument Factory).Gifted but headstrong, Barrow fell out with Everest and was discharged from service in 1839. On return to England Barrow set up his own manufactory and supplied instruments to the GTS.

For repairs during the field trips, Everest took along Arcot-born Syed Mir Mohsin Husain (d. 1864) whom he had hand-picked. Brought from Madras to Calcutta by one of Everest's predecessors Col.Valentine Blacker (1778-1826), Mir Mohsin was appointed in 1824 as an instrument repairer at the Surveyor General's office at a monthly salary of Rs.25. In 1836 he was appointed a sub-assistant at the GTS. On Everest's recommendation the company appointed Mohsin successor to Barrow, but with a lowered designation of 'Head artificer to the department of scientific instruments'[7] Overcoming prejudice in high quarters, Everest finally in 1843 got Mohsin appointed as Barrow's successor with the same official designation, if not the salary. Mohsin was given a monthly salary of Rs .250. Markham[8] wrote about Mir Mohsin: 'though he could not read English, he would have taken a leading place even among European instrument makers'.

The Instrument Department got busy remodelling astronomical altazimuths to serve as geodetic theodolites, by replacing their circles and axes, using parts from older instruments and making new ones. In 1833 Barrow reconstructed to Everest's design, the old Cary's theodolite, replacing the vertical circle with one taken off another instrument. Barrow made a new horizontal circle and hand-divided it himself- a singular achievement.

Not only were old instruments modernized, new ones were also modified to meet Everest's exacting standards. Thus, the great 3 ft theodolite and two identical 18 in theodolites made by Troughton & Simms under Everest's supervision and received at Calcutta in 1830 had to be improved upon before they could be used.

The crowning glory of Mir Mohsin and Everest was the treatment of two altazimuth instruments received from Troughton &: Simms in 1832. The two, each with a 3 ft vertical circle and 2 ft horizontal circle, were found to be radically defective in design when later put to use. In 1839 the brass horizontal circles of both were replaced by cast-iron ones, which after Barrow's refusal were hand-divided by Mohsin Hussain using an engine designed by Everest. (This was before William Simms devised his self-acting dividing engine). For this outstanding work, Mir Mohsin received from the Governor General an increase in salary and an equivalent of £200 'the sum that would be charged for the same work by the first rate makers in London'. In 1840, Hussain constructed an 18 in. theodolite, entirely by himself, except for the object glass of the telescope and lenses of the eyepieces and microscopes.

The Instrument Department also undertook non-survey work. Thus in 1835, Barrow excellently repaired the Madras 5 ft transit instrument that Taylor was using, although the instrument was gone from the Observatory 11 months. Barrow received Rs 203 for the repair and return freight. In 1874-75, the Department manufactured 3999 instruments, repaired 2391, and examined 2067.

In 1862 the Secretary of State for India asked Lt - Col. Alexander Strange FRS (who had been a member of the GTS 1847-60) to supervise and test all instruments destined for India, and an observatory was set up for the purpose at Lambeth. The average yearly cost of the instruments for the five year period 1873-77 was £ 16343. The cost of inspection was £ 584, including £ 350 for Colonel Strange's salary[8]. The instruments sent out for the GTS included the following[37].

i. Two zenith sectors by Troughton & Simms (received 1869 and 1871).

ii. Two identical transit telescopes (marked 1 and 2); 5 in. aperture, 5 ft focus; by T.Cooke & Sons (1872).

iii. Two drum chronographs (A and B) with electrical apparatus; for use with above, by Eichens & Hardy of Paris (1872).

iv. Three 8-day astronomical clocks with mercurial pendulums, by Frodsham of London (1872).

v. A 3 ft theodolite by Troughton & Simms (1874).[38]

Also received were

vi. Two smaller transit instruments by T.Cooke & Sons.

vii. Two 12 in. vertical circles (German form) by Repshold of Hamburg.

The first use of the transit telescopes was in 1872 to electro-telegraphically determine the longitude difference between Madras and Bangalore under John Herschel (son of Sir John Herschel). Telescope 2 was found defective and repaired by Doderet in Madras in 1875, who also carried out the changes in the electric recorders[36]. In 1896 telescope 2 and chronograph A were sent to Madras for later use at Kodaikanal.[28] (The telescope is still at Kodaikanal, whereas the chronograph without the electrical arrangements is now kept at Bangalore).

This Strange set of instruments was the last consignment of major positional- astronomy instruments received in the 19th century.

6. LUCKNOW OBSERVATORY (1831-49)

In 1819 the Nawab of the rich province of Oudh (correctly, Avadh, corresponding to the eastern part of the present Uttar Pradesh) Ghazi-uddin Hyder, on the instigation of the British, declared his independence from the tottering Mughal empire at Delhi and proclaimed himself the King. The second King (1827-37) Naseeruddin Hyder (who had a European wife) founded an Observatory at the capital city of Lucknow.

Although the Observatory belonged to the King, its scientific control was in the hands of the British, the Astronomer's appointment being made by the Governor General. Major James Dowling Herbert (1791-1833) came to Lucknow with good credentials. He was at that time occupying the number two position at Calcutta as Deputy Surveyor General and Superintendent of Revenue Surveys (salary Rs 750 pm). He had earlier for a short period officiated as the Surveyor General, and his name had been mentioned to take over Everest's responsibilities as Superintendent of the GTS if Everest relinquished charge on grounds of health. Herbert joined at Lucknow in December 1831, and promptly ordered the best available instruments for the Observatory.

Herbert died in 1833, and was succeeded by Lt - Col. Richard Wilcox (1802-48). The lure of high salary (Rs 1000) had again attracted a capable man to Lucknow. Since 1832, Wilcox had been an astronomical assistant at the GTS, with a salary of Rs 618 pm. Everest wrote about him 'Lieut Wilcox is a person highly able, and likely to qualify himself in a shorter time than any person in the Department'. Herbert describes him as 'one of the cleverest young man we have'. He was in addition a distinguished oriental scholar[7]. Wilcox joined at Lucknow in 1835 September. His place at the GTS was taken by Andrew Scott Waugh who subsequently succeeded Everest.

Wilcox built the Observatory, put up the instruments, organized the plan of observations, and brought the observatory into a state of high efficiency[7] The Observatory was ready for use in 1841. It was the best equipped in India, certainly better than Madras, and was in fact on par with Greenwich and Cambridge. It boasted of (i) a mural circle of 6 ft, (ii) an 8 ft transit, and (iii) an equatorial of more than 5 in. aperture - all three by Troughton & Simms. The clocks were by Molyneux.

Wilcox set out to emulate Taylor at Madras who was engaged in the work on his monumental 'Madras catalogue'. Wilcox himself observed with the mural circle. 1 believe that our transit observations - in which I take no part myself (being left to the 'Hindoo lads')- will compete with those of any observatory'. The equatorial was used for observing the eclipses of Jupiter's satellites. I have observed but few occultations, on account of their requiring time for the previous computations ....'.

The results from these excellent instruments were never published. Wilcox died in 1848 October; and the Observatory itself was abolished in 1849 by the King on the ground that the great outlay incurred in maintaining it had produced no advantage whatever to the state or to the people and learned of Oudh'. It is reported that a memorandum to the King had asserted that 'the Europeans and not Indians are benefited by this Observatory'.[29]

When Avadh was annexed by the British in 1856, there was a move by the Surveyor General Sir Andrew Waugh to use these instruments for an observatory at Calcutta. The Observatory was however ransacked in 1857. Lt James Francis Tennant of the Bengal Engineers was a part of the British force that recaptured Lucknow. He found that though the building itself was 'unhurt', all the instruments had perished.

In the mean time all the records of the Observatory, reduced as 'well as unreduced, were eaten up by insects. Thus ended a first class observatory whose results could never see the light of day.

7. TRIVANDRUM OBSERVATORY (1837-52)

The King of Travancore, Raja Varma (1813-47) (better known as Svati Tirunai), set up an observatory at Trivandrum, in 1837. The astronomer John Caldecott (1800-1849) furnished it with

i a transit instrument by Dollond, of 3¾ in. aperture;

ii a 5 ft diameter mural circle by Dollond, with a 4 in. aperture telescope;

iii a mural circle by Jones;

iv a portable altazimuth by Troughton & Simms;

v a transit clock by E.J.Dent; and

vi a mean time clock by E.Wrench.

In 1842 there was received

vii a 5 in. aperture, 7 ft focus English plan equatorial by Dollond.

viii There was also a smaller equotorial of 4.3 in. aperture and 5 ft focus.

By 1852 these instruments had become so dilapidated that the Observatory Director John Broun FRS gave up astronomy and concentrated on magnetism and meteorology.

8. POONA NON-OBSERVATORY

And then there was an observatory that wasn't to be. Its founder was Capt. William Stephen Jacob (1813-62) of the Bombay Engineers who worked for the GTS from 1833 to 1843, becoming First Assistant in 1837. In 1842 Jacob set up an observatory at Poona to house his 5 ft focus equatorial by Dollond in a folding roof rather than rotating (expense £25). On the basis of the work done at Poona, while holding the post of Assistant Super-intendent of Roads and Tanks in the Public Works Department, Jacob was invited to come over to Madras Observatory which he did in 1849 by closing down his own observatory.

Jacob was always dogged by ill-health. He left for England in 1858 on leave, and resigned his post the next year. In 1859, Jacob wrote to R.C.Carrington, the Secretary of the Royal Astronomical Society[33] 'the East India Company has expended large sums in the promotion of science, witness the Trigonometrical Survey, and the Magnetic and Meteorological Observatories, but though astronomy has not been altogether neglected, it has scarcely been allowed the prominence that it merits both by its intrinsic importance and from the advantages offered by the Climate.'

In 1861 the British Parliament gave a grant of £1000 to the Royal Astronomical Society 'in aid of the proposed temporary maintenance of an Observatory near Poonah'. Jacob bought a 9 in. aperture telescope by T.Cooke &: Sons 'at his own expense and cost' (£550) and was given £500 (£100 for purchasing a chronometer and other minor instruments, .£400 for package, freight and first expense on arrival). Jacob was to hold the charge of the Observatory for three years, but never got to using the remaining grant. He arrived at Poona in 1862 August, but died two days later of 'violent lever attack' 'though leaches were freely applied'.[35]

The 9 in. telescope was subsequently put on sale in England.[7]

9. 19TH CENTURY POSITIONAL ASTRONOMY - A CRITIQUE

We have seen that astronomical activity in India in the 19th century followed two distinct channels: pure astronomy as represented by the Madras Observatory, and practical astronomy as represented by the Great Trigonometrical Survey of India. In the early years, till 1829, there was hardly a distinction between the activities of the Observatory and the Survey. Madras Observatory was the reference meridian for all survey work, and the early astronomers Michael Topping, John Goldingham, and John Warren actively participated in the GTS work, being officially co-designated (till 1810) Madras surveyors. Between 1794 and 1810 the Observatory ran a surveying school to train India - born European boys (then called natives) as assistant surveyors. The last astronomer to do survey work was Thomas Glanville Taylor who assisted George Everest at Calcutta in 1831.(The first astronomer without any surveying connection whatsoever was Norman Robert Pogson who joined in 1861).

After this, the two streams, (Madras) astronomy and trigonometrical survey, increasingly separated. For reasons of state, practical astronomy received all the favours, while pure astronomy emerged as a poor cousin.

The relative importance of the two streams of astronomy is best brought out by economics. In 1801 the Survey Superintendent's monthly salary was fixed at Rs.980, when the Madras Astronomer was receiving Rs.672. Seven decades later, in 1877, the Superintendent's salary had gone up to Rs.2565, whereas the Madras Astronomer received a paltry Rs.800. Fifteen officers of the survey were drawing more than the Astronomer, three of them being Fellows of the Royal Society.[7]

Significantly, while military officers were permitted to serve on the GTS, they were not allowed to take up the 'civil' appointment at Madras Observatory.

The attitude towards pure astronomy is best brought out by a little-known incident. In 1834, on orders from the Government, instruments were issued to John Cumin, the former Astronomer at Bombay, for the observation of the opposition of Mars. The Surveyor General, George Everest, made a strong protest against the loan, sayings

'...The discoveries which the late astronomer of Bombay is likely to make in science would hardly repay the inconvenience occasioned by retarding the operations of the Great Trigonometrical Survey...'

10. ADVENT OF PHYSICAL ASTRONOMY (1874)

Although spectroscopic and photographic techniques had been used in the Indian observations of the solar eclipses of 1868, 1871 and 1872, it was the 1874 December 9 transit of Venus and a belief in a connection between the sun and the famines that led to the beginning in India of solar physics - or physical astronomy as it was then called.[39,40]

At the initiative of the Astronomer Royal, Sir George Airy, transit of Venus observations were planned at Roorkee and Lahore, under the supervision of Col. James Francis Tennant (later Lt-Gen.) of the Royal Engineers. Note that it was Tennant and not Airy's *bete noire*, Norman Robert Pogson, the Madras Astronomer, who was asked to do this work. The following instruments were sent out from England.

i. Photoheliograph by Dallmeyer

Precisely similar to the five instruments made for the British transit of Venus expeditions, it had a 4 in. aperture lens that made a 4 in. diameter solar image on 6 in. square photographic plates. It had originally been ordered by Dr Warren de la Rue, who was persuaded to give it up for India's use. It was used at Roorkee by Capt.J.Waterhouse Superintendent of the Mathematical Instrument Department, Calcutta, who took over 100 photographs of the solar disc. These pictures were sent to Greenwich where they were reduced by Capt. G.L.Tupman who wrote[42] 'There is only one really sharp image in the whole collection, including the Indian and Australian contingents, and that is one of Captain Waterhouse's wet plates taken at Roorkee.....'.

ii. A 6 in. aperture, 82 in. focus equatorial by T.Cooke & Sons, 'of their usual pattern'. Its construction was supervised by Col.A.Strange. It was also set up at Roorkee. Eventually this telescope reached Kodaikanal via South Kensington and Poona. Its mounting now supports Pogson's 8 in. telescope at Kodaikanal.

iii. A small transit instrument,

iv. a standard and two journeyman clocks, v.

v. a chronograph,
all by T. Cooke & Sons.

Tennant suggestion for setting up a solar observatory at Simla with these instruments was turned down and he was asked to send the instruments back to England. However, where Tennant failed, Joseph Norman Lockyer succeeded by using his good offices with Lord Salisbury, the Secretary of State for India, who had visited Lockyer's laboratories at South Kensington a number of times and shown great interest in his work.[39]

Lockyer in 1877 suggested[39] that the photoheliograph already in India should be used for daily photography of the sun; and 'the remaining instruments should certainly come home at once. If not contrary to Indian regulations, I would beg to be allowed the use of them....'

Salisbury accepted the suggestions, writing to the Governor General of India on 1877 September 28 ... and viewing the fact that a study of the condition of the sun's disc in relation to terrestrial phenomena has become an important part of physical investigation, I have thought it desirable to assent to ..... obtain photographs of the sun's disc by aid of the instrument in India .... . 'The stand of the photoheliograph will be retained in India, and a fresh tube will be sent there to replace that used by Colonel Tennant (which had been found defective) .... The other instruments may also be sent to England, and will be placed in the custody of the Science and Art Department which has offered to take charge of them'[39].

The telescope tube was replaced by the Astronomer Royal and thus, directly on orders from the Secretary of State for India, solar photography started at Dehra Dun in 1878. In 1880 a bigger photoheliograph -of 6 in. aperture, 9 ft focus objective giving 12 in. diameter pictures - was sent out by the Solar Physics Committee. Also arrangements were made to modify the older one to give 8 in. pictures, instead of 4 in. Direct photography continued at Dehra Dun till 1925 with some years of overlap with Kodaikanal.

11. TAKHTASINGHJI'S OBSERVATORY POONA (1888-1912)

This was the first modern astrophysical observatory in the country, and result of efforts of Kavasji Dadabhai Naegamvala (1857-1938) a lecturer in Physics at Elphinstone College Bombay. Armed with a 5000 rupee grant from Maharaja Takhtasinghji of Bhavnagar (in Gujarat) and a matching amount from the Bombay Government, he established an observatory at Government College of Science (now College of Engineering) Poona where he had shifted in the mean time.

The chief instrument was a 16½ in. aperture silver-on-parabolic glass Newtonian with a 4-inch finder attached. This telescope by Grubb along with its £250 observatory dome was inspected at the Indian Government's Lambeth Observatory in 1887 or 1888 before being sent to Poona, where it was installed in 1890, though the building had been ready in 1888.

In 1874 the Government of India had purchased a 6-inch equatorial by T.Cooke & Sons for observing the transit of Venus from India. After the transit (in 1879) it was loaned to Sir Norman Lockyer at South Kensington (see section 10). The India office also purchased two spectroscopes from Hilger (one solar, the other stellar) for Lockyer's use. The equatorial was also inspected at Lambeth and along with the spectroscopes was sent to Poona in 1885.[43] (In 1893 the telescope and the spectroscope were asked to be sent to Madras for use at Kodaikanal Observatory which came up only in 1899. Madras however received only one of the spectroscopes). Ironically, Naegamvala's first use of the large telescope was to prove his mentor Lockyer wrong. Naegamvala showed in 1891 that the chief nebular line in Orion was sharp under all circumstances and therefore could not be the remnant of a magnesium band as Lockyer had suggested. In other words William Huggins and James E.Keeler were right.

Lockyer's bland reaction is amusing. Describing Poona Observatory, he wrote[45] in 1898 'Some spectroscopic work of preliminary character was done during 1891, but it was found that the instrument used was altogether lacking in stability and was very weak in its driving parts...'.

The telescope was sent to Grubb for modifications and was received back in 1894. It was now 'a Cassegrain reflector of 16½ in. aperture and 127 in. focus, adapted both for visual and photographic work, and supplied with electrical control'. To this was attached a 6 in. achromatic finder with filar micrometer and solar eye piece.

The telescope underwent yet another change when in 1897 the mirror was replaced by a 20 in. aperture, 11 ft. 3 in. focus mirror by Dr A.A. Common. No results appear to have been published using this telescope.

The Observatory was closed down in 1912 on Naegamvala's retirement and instruments were transferred to Kodaikanal from where we get their description. They comprised the following :

i. 20 in. reflecting telescope by Grubb. Mirror by Dr A. A. Common (now called Bhavnagar telescope).

ii. 6 in. Cooke photo-visual equatorial telescope.

iii. Two prisms of 6 in. aperture for use with the above.

iv. 12 in. Cooke siderostat.

v. 8 in. horizontal telescope.

vi. Large grating spectroscope, by Hilger.

vii. An ultraviolet spectrograph, by Grubb.

viii. Sidereal clock, by Cooke.

ix. Mean time chronometer, Frodsham No 3476.

The Poona Observatory was a clear case of history repeating itself. Though the best equipped in the country when set up, Maharaja Takhtasinghji's observatory turned out to be a one-astronomer observatory, closing down with Naegamvala's retirement.

The Kodaikanal Observatory, after a shaky start, rose to great heights, and was intact when the time came for modernization.

12. KODAIKANAL OBSERVATORY (1899)

Although the need for a modern observatory as a successor to the one at Madras for research in the newly opened field of physical astronomy had been felt for many decades, it was only in 1891 on the death of

Pogson after a 30 year uninterrupted stint as the Director of Madras Observatory that the question of a new observatory was taken up in earnest.

The severe famine in the Madras Presidency in 1876-77 was taken to underline the need for a study of the sun so that monsoon patterns could be better understood. Thanks to the efforts of John Eliot[44], Meteorological Reporter to the Government of India (later renamed Director General of Observatories), it was finally decided in 1893 - overruling Norman Lockyer's[45] objections supporting Naegamvala's case - to establish a solar physics observatory at Kodaikanal in the Palani Hills of South India with the Madras Astronomer Charles Michie Smith as the Director[46] to transfer all astronomical activity from Madras to Kodaikanal; and to place the new observatory under the control of the Central Government. Kodaikanal Observatory came into existence on 1899 April 1, with the following instruments that had in the mean time been collected at Madras from a variety of sources[28]:

i Photoheliograph called Dallmeyer No 4; this was one of the five identical photoheliographs made by John Henry Dallmeyer (1830-1833) for the British transit of Venus expeditions[47]. With a 4 in. aperture, 5 ft. focus object glass, it was modified after the transit (in 1884) to give an 8 in. diameter solar image. Similar to the ones in use at Greenwich and Dehra Dun, it was received at Madras in 1895 April on loan from Greenwich. (It is now at Bangalore, without the optics)

ii Spectrograph received in 1897, consisting of a polar siderostat with an 11 in. aperture plane mirror; a 6 in. aperture, 40 ft focus lens; and a concave grating. The siderostat and the lens were made by Sir Howard Grubb, and the rest of the instrument by Adam Hilger. (The siderostat still survives and is at Bangalore.)

iii 6 in. aperture telescope by T.Cooke & Sons. Made for the 1874 transit of Venus observations at Roorkee, it was loaned to Lockyer, along with a three-prism solar spectroscope by Adam Hilger. Sent in 1885 to Poona, it was transferred to Madras in 1893 (see sections 10 and 11).

iv Transit telescope and chronograph. Already discussed in section 5, this 5 in. aperture, 5 ft. focus equatorial was made by T.Cooke & Sons for the Great Trigonometrical Survey of India, which sent it to Madras along with the accompanying galvanic drum chronograph made by Eichen & Hardy of Paris.

v 6 in. equatorial by Lerebours & Secretan. An old Madras telescope of 1850 vintage, it was remodelled by Sir Howard Grubb in 1898 who mounted on it a 5 in. focus photographic lens, and provided the telescope with a new driving clock.

The polar siderostat and the 40 ft focus lens, and Dallmeyer No 4 were taken to Shahdol (now in Madhya Pradesh) and adapted for photography during the total solar eclipse of 1898.

In 1902 September a calcium-K spectroheliograph was ordered from Horace Dar- win's Cambridge Scientific Instrument Company[48] . Its construction was supervised by H.F.Newall, and it arrived in 1904 August, at a cost of £1300. This 12 in. aperture, 20 ft. focus solar telescope was used in conjunction with a £440 Foucault siderostat incorporating an 18 in. aperture plane silver-on-glass mirror made by T.Cooke & Sons. In 1903, a dividing engine was received from the same company.

John Evershed's arrival in 1907 heralded the observatory's golden age. He made a prismatic camera using the prisms he had brought with him; and got the spectroheliograph into working order. Evershed also built a number of spectrographs, and continued his work on radial motion in sunspots (the Evershed effect). In 1911 Evershed finally made an auxiliary spectroheliograph and bolted it to the framework of the existing instrument so that now the sun could be photographed not only in calcium K light but also in hydrogen alpha. This was the first and only time that a state-of-the-art pure astronomical instrument was built in India.

In 1912 instruments were received from Poona on the closure of Takhtasinghji's Observatory. The 20 in. Bhavnagar reflector was installed only in 1951. In 1933 a Hale spectrohelioscope was received as a gift from the Mount Wilson Observatory.

Thanks to Anil Kumar Das (1902-1961) and the International Geophysical Year that started in 1957, Kodaikanal acquired three instruments in 1958: (i) a Lyot hydrogen-alpha heliograph (£2234) with a 15 cm aperture objective, from Paris (ii) A Lyot coronograph (£8126) with a 20 cm aperture, 3 m focus objective from M/s REOSC, Paris. The corono-graph has never really been used. (iii) A tunnel telescope of 38 cm aperture and 36 m focus (Rs 525000), from Sir Howard Grubb Parsons. The tunnel telescope has been the main solar physics telescope in the country, ever since. This was the last consignment of instruments to reach Kodaikanal Observatory.

In 1961 with the appointment of Manali Kallat Vainu Bappu (1927-1982) the emphasis shifted towards modernisation of stellar astronomical facilities, with the establishment in 1968 of an observatory at Kavalur[48].

13. NIZAMIAH OBSERVATORY[49] (1901)

Nizamiah (i.e. Nizam's) Observatory was established in 1901 by a rich nobleman Nawab Zafar Jung at his estate at Phisalbanda in Hyderabad. His chief instruments were (i) a 15 in. refractor, by Howard Grubb; and (ii) an astrograph, with an 8 in. aperture photovisual doublet Cooke lens.

Showing foresight, Zafar Jung had taken the Nizam's (i.e. the King's) permission for the name and had also ensured that after the founder's death, the Observatory would be taken over by the Government. Jung died in 1907; the observatory was shifted to Begumpet in Hyderabad itself with Mr.A.B.Chatwood as the Director.

The first instrument to be installed end of 1909 was the astrograph which was housed in a 25 ft dome by T.Cooke & Sons. Using it, the Nizamiah joined the international 'Carte du ciel' program. The 15 in. Grubb was installed only in 1922; in the mean time (1915-22) its objective was used at Kodaikanal.

The Observatory acquired, in 1939, a Hale spectrohelioscope made by Howell & Sher-burne of Pasadena. In 1958, a 1.2m reflector was purchased from J.W.Pecker & Co. of Pittsburg using a rupee grant from the US government. A new site was chosen for the observatory near the two villages of Japal and Rangapur, some 50 km from Hyderabad. The 1.2 m reflector was installed in 1968 at the Japal-Rangapur Observatory and remains its mainstay.

14. UTTAR PRADESH STATE OBSERVATORY, NAINI TAL (1954)

This observatory was set up in April 1954 at Varanasi under the honorary directorship of A.N.Singh, the Principal of the newly established D.S.B.Government Degree College at Naini Tal. Its early instruments included[50] i a gravity-driven 25 cm refractor, by T.Cooke & Sons,

ii a 13 cm transit telescope,

iii a set of quartz clocks by Rhode & Schwartz.

In November 1955, with Vainu Bappu as the Director, the Observatory was shifted to Manora Peak, Naini Tal. The Observatory's biggest telescope is a 1m reflector by Carl Zeiss Jena set up in 1972 (its twin is at Kavalur).

15. CONCLUDING REMARKS

The first half of the 20th century saw astronomy in India represented by two observatories: the Imperial Government's Kodaikanal Observatory; and Osmania University's Nizamiah Observatory.

The real reason for the establishment of Kodaikanal Observatory was the need of the British astronomers to collect good quality data on the sun, which as Lockyer pointed out was not so obliging to Britain itself. The solar connection with the monsoons (which even today determine India's prosperity) was used as a convenient reason to strengthen the case for a solar observatory in India. Nizamiah observatory, on the other hand, was set up for no reason other than cosmic curiosity. During the British period, Kodaikanal's mainstay was the state-of-the-art instruments made by Evershed himself.

It was after India's independence in 1947 that Kodaikanal Observatory received the new Government's support in the name of astronomy for pleasure and prestige. Thus, International Geophysical Year was used to buy new equipment for solar studies.

We have closed our account in 1960. This is the year when Bappu Joined Kodaikanal as its Director. He set out to update stellar astronomy. As a result of his efforts a new observatory was set up at Kavalur (Javadi Hills, Tamil Nadu), which is now named after him, and has a 2.3 metre telescope. In the mean time a small solar physics observatory has come up at Udaipur, and an infrared 1 metre class telescope at Gurushikhar (Mount Abu).

It may, however, be pointed out that India's infrastructural facilities have been especially conducive towards radio and mm wave telescopes.

The post-1960 astronomical facilities will be treated separately.

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13. Topping's description of the Observatory (ref.l4) says that it was established in 1787. If it is not a misprint, it could mean that the observatory came up while he was out of Madras (i.e. in 1786 November or December) and he learnt about it on his return. It is not possible to say where exactly in Egmore Petrie's Observatory was located, because old records refer to garden houses with respect to each other, and not to any landmarks.

14. Michael Topping: Description of an Astronomical Observatory erected at Madras in 1792, by order of The East India Company, Madras, 24th December 1792. RAS copy of the MS is without any illustrations; IOLR copy has a sketch of the Observatory. The damaged Bangalore copy contains all the illustrations referred to in the text; and an appendix written a little later.

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46. Michie Smith received support from the Astronomer Royal: W.H.M.Christie (1898) Report on Indian Observatories.

47. Derek Howse in his History of Greenwich Observatory, Vol.3.(Taylor & Francis, Lon- don) mistakenly attributes the construction to J.H.Dallmeyer's son Thomas Rudol- phus Dallmeyer (1859-1906) who was only 15 at the time of the 1874 transit.

48. Annual Reports of Kodaikanal Observatory 1900-1961.

49. Kochhar,R.K. & Menon,M.G.K. (1982) Bull. Astr. Soc. India. 10, 275.

50. Sanwal.N.B. (1983) in Nizamiah Observatory, Platinum Jubilee Souvenir 1908-1983. (ed.: G.M.Ballabh) Osmania University, Hyderabad. The year 1908 is the year of the Observatory's

taking over by the Government, not its founding. Also see Sanwal.N.B. (1983) Bull. Astr. Soc. India 11, 349

51. 25 years of Uttar Pradesh State Observatory, Naini Tal (1979), UPSO.