12 INTRODUCTION OF MODERN WESTERN ASTRONOMY IN INDIA DURING 18-19 CENTURIES

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INTRODUCTION

Ancient Indian Astronomy

The great antiquity of astronomical activity in India is quite a well-know fact of history. According to one account[1] astronomical calendar calculations existed presumably as early as the 14th century B.C. Even if one does not agree with this date, it is fairly known today that ancient Indian astronomers were familiar with the calendaric astronomy[2] in the period 1300 B.C. to 300 A.D.[3] In any case it is well-established that Indian calendaric astronomy was developed further into the planetary astronomy in the first few centuries of the Christian era when Sanskrit astronomical treatises, the siddhântas, were compiled. Out of the five siddhântas as reviewed by Varāhamihira (6th c. A.D.),[4] a late version of one of them, the *Sūrya-siddhānta* is still extant today.[5] The astronomical tables as compiled in ancient India[6] were therefore based, besides on observation,[7] also on the modified pre-ptolemaic rather Indian epicyclic-eccentric model of the planetary motion as described and further developed in those treatises and their commentaries.[8]

Early Indian Observatories

The history of the establishment of early astronomical observatories[9] in India has not been worked out in detail. The following references may be quoted here from literature.[10]

(i) According to the first Mughal King of India, Bābur (1483—1530), observatories existed in the cities of Ujjain and Dahār. Employing Bābur's remarks the observatory at Ujjain is estimated to be extant in the first century B.C. This period may be an over-estimation, though not impossible. After all Ujjain was the Greenwich of India from ancient times, even known to Greeks as *οζηνγ* and to West-Asian Islamic astronomers as the cupola of the earth (*qubbatul arḍ*).

(ii) 'Abd Al-Rashīd Al-Yāqutī (15th C.) reported an observatory in the city of Jajili.

(iii) 'Abdullāh Shukrī Al-Qunâwī (16th C.) reported also an observatory at *al-Kankadaz* or *al-Dharkanak*. These cities have not been identified so far, and no remains of those observatories exist today. We may mention that in the West-Asian astronomical literature, *Kanak-dar* is said to be the location somewhere in the Far East of Arabia corresponding to the "Longitude Zero". One may identify it with Ujjain.

(iv) Maharaja Swai Jai Singh II (1686—1743) of Ambar was commissioned by Emperor Muḥammad Shāh (reign 1719—1748) to build a number of observatories. Jai Singh got constructed five observatories at Delhi (1724/28), Jaipur (1734), Banaras (1737), Ujjain and Mathura[11 12]. The last one is no longer extant. In these observatories are extant even today masonary and metal instruments (of pre-telescopic era), which were constructed according to Ulugh Beg's school of astronomy at Samarqand,[13] as also those which were of Jai Singh's own invention, as claimed by him in *Zīj-i Muḥammad Shāhī* (here-after referred as ZMS, and with folios of Aligarh manuscript). Here, however, we shall not be concerned with that aspect of Jai Singh's astronomy.[14] What is more significant than the above-mentioned instruments is the work of Jai Singh from the standpoint of modern post-telescopic observational astronomy. It is not widely known that Jai Singh *did make use of a telescope and with its help carried out some observations.*

Jai Singh's Reception of European Astronomy

The Use of Telescope

In the text of his *zīj*, Jai Singh clearly states that "telescopes are constructed in my kingdom" and he enumerates the following observations carried out with their help.[15];

(i) the ellipticity of the orbits of the Moon and the Sun;
(ii) the phases of Mercury and Venus;
(iii) the existence of sunspots and their rotation;
(iv) the four satellites of Jupiter;
(v) the ellipsoidal shape of Saturn; and
(vi) the slight motion of the "fixed" stars, with different velocities.

We have compared several manuscripts of ZMS, extant at Tashkent, British Museum Cambridge, Aligarh, Bombay, Jaipur, Lahore, Tonk, Delhi and Bankipore, and have found that in all those manuscripts the above-mentioned particular passage is given. Till to-date in only one manuscript of ZMS[16] that passage is not given. One would like to conjecture that it was copied from the "first" edition of ZMS compiled before 1728—29 when Jai Singh sent an embassy to Portugal ! In fact such a manuscript of ZMS, circa 1727 is supposed to be extant in Sipah Salar Library, Tehran.[17]

As a matter of fact, the use of telescope in the middle of the 18th century for astronomical purpose is hardly surprising, since historical records show that European telescopes were available in India as early as 17th century. In the first quarter of the seventeenth century, prospectives,[18] i.e. telescopes, were presented to Emperor Jahangir (reigned 1605—27) by Sir Thomas Roe. Thereafter it became a general practice for the Mughal nobility to get telescopes as presents.[19]

It may also be noted that a telescope (*dūrbīn*), as a kind of spectacle used by boatmen and also for reconnaissance of enemy's army, was already known to some Indian compilers of Persian dictionaries of 18—19th centuries.[20] Thus the telescope as a useful instrument was already known in 17th century India and it is of course certain that Jesuit geographers/cartographers used them in India for carrying out astronomical observations. Since Jai Singh had developed close contacts with Jesuits in order to familiarize himself with the European astronomy, he sent in about 1728—29 an embassy of Jesuits and Indian astronomers to the then Portuguese King.[21] It is highly probable that a telescope (besides other astronomical books) should have been presented to Jai Singh by the Jesuits after circa 1730.[22] Consequently like Galileo, Jai Singh was the first Indian to use telescope for *astronomical observations* in India. However, whether he used telescopic observations for the compilation of ZMS is still under study, to be reported elsewhere.[23]

We may also mention here another evidence regarding the use of telescope, namely the diagrams corresponding to the five observations mentioned above. These diagrams (see photograph)[24] have been found by us in a number of manuscripts, for instance the extant one at Lahore, Bombay, Cambridge and Bankipore/Patna, but *not* in the manuscript of British Museum. Only in one of those manuscripts (at Bombay) a selenographic diagram of the lunar surfcce is given. All of these diagrams are on the margins of some folios but not on the folio where the aforementioned five observations are listed.[24]

We would like to digress here for a short while in order to show that some Europeans like Kaye have treated the Asian contribution to science from *Eurocentric* standpoint unobjectively,[25] and consequently have suppressed at times the significant information. This is exactly the case with the use of the telescope by Jai Singh and his six rediscoveries mentioned before. Kaye in his monograph[26] quotes the French translation of Sayid Ahmad Khan's work on monuments of Delhi by Garcin de Tassy in which those rediscoveries are clearly listed. About the observatory *(Jantar Mantar)* at Delhi it is mentioned therein.[27]

> "Dans cet observatoire il n'était pas nécessaire
> de faire le calcul des divers aspects lunaires,
> du lever et du coucher des étoiles et des maisons
> de la lune, parce qu'a l'aide du télescope toutes
> ces choses se voient de jour".

Kaye did not breathe out a single word about the use of telescope by Jai Singh or his rediscoveries. One the contrary, he was of the opinion that Sayid Ahmad's "account is not very reliable", and "Jai Singh's apparent indifference to European achievements is rather remarkable". A blatant dishonesty on the part of Kaye, who did not forget to mention in footnotes the European innovations: the aerial telescope of La Hire or the first mention of telescopic sights in 1667.[28]

Notwithstanding the above-mentioned use of the telescope by Jai Singh, we do exclude the possibility that he employed the telescope more as a device just for observations (mapping the planetary surface, planetary and star fields) rather than as a measuring instrument, see the photograph. For Jai Singh it was quite natural to verify the famous Galileu's observations, *as it had happened also in Europe.* According to Van Helden,[29]

> "We tend to think that the full potential of the telescope as a research instrument was *immediately* apparent to Galileo and his contemporaries; this was *not* the case. During the first twenty-five years of its existence the telescope remained primarily an instrument for terrestrial use, usually for naval or military purposes. When one turned such an instrument to the heavens, it was *usually to see for oneself the discoveries of Galileo.*"

If therefore "the astronomical telescope was not particularly popular for the first half-century after its invention",[30] and only "between 1650 and 1685 astronomers finally came to realize the full potential of the new instrument", that is, "the telescope become a full-fledged instrument which was used not only for discovery, also for measurement",[31] we can not blame Jai Singh for not compiling his tables with the aid of the telescope; we do not know presently at all as to what kind of telescope "was constructed" by him and which in-built defects existed in his telescopes or those presumably presented to him by the Jesuits.

We would like to recall briefly here the optical problems and other defects in the refractors of the 17th century,[32] in order to understand the historical context in which the general development of telescope took place. In that context one could then try to understand the limited use of the telescope by Jai Singh.

(1) The spherical or chromatic aberrations of the lenses should be mentioned first. Those defects could be eliminated fairly well by using very long tubes[33], but aerial telescopes introduced other problems as follows.

(2) Long wooden tubes gave rise to defects like warping, shrinking or swelling. Besides, the telescope became very unwieldy to mount, and to operate by means of rods and pulleys. A stable image in the small field of view was a problem so also the alignment of the objective and eye-piece lens.

(3) Until the invention of a ctoss-wire in the eye-piece and also of the micrometer by Gascoinge (1619-1644) already in 1640/41[34] the telescope could not

be employed as an instrument of measurement, say, determination of the angular distance between two heavenly objects. In fact, initially telescopes were mounted on angle-measuring instruments like quadrants, sextant as *telescopic sights*. However, a good deal of controversy then arose about the accuracy achieved. Whether the accuracy measurement was more by telescopic than by open sights became debtable. A very strong supporter of the latter was Hevelius (1611-1687) of Danzig, who corresponded actively with Hook (1635-1703) and between 1676-1679 with Astronomer Royal Flamsteed (1646-1720), both of whom were in favour of telescopic sights,[35] Let us take note of this stage in the development of telescope in the very person of Johann Hevelius of Tychonic school.

In support of open and bare sights fixed on his quadrant of 5 feet radius and some of 6 ft. he argued,[36]

> "I question whether these telescopic Sights, so near the Eye, can discover the smallest Stars much more accurately, than our plain Sights, which are distant from each other Six or Nine feet. For, though by these Telescopic Sights, one may see the object more distinctly; yet because they are so nigh to the Eye, one may err, more than 'tis possible by our plain Sights, that are so far as under."

One should not forget that Hevelius himself constructed initially telescopes of less than 13 feet focus and used them for mapping the lunar surface; that work was published in his *Selenographia* in 1647. Actually later he became a great specialist in making long telescopes of 60, 70 feet focus and finally of 150 ft, which he described in his famous work *Machinae Coelestis pars prior* (Gedani 1673)[37] All the same he rejected stubbornly the use of telescopic sights altogether. It is said that his claim to achieve an accuracy of less then 1 minute of arc for his instruments with open sight was admitted unbelievingly by Halley after his visit to Danzing in 1679.[38] Repsoli had had tried to explain Hevelius' viewpoint by assuming that he was gifted by a remarkably sharp eyesight and was so much accustomed with his techniques of observations, that he could achieve quite extraordinary accuracy of measurement. Further, he used to have fixed stable, non-vacillating instruments of Tychonic type and his metal quadrants and sextants were not less than of 3 ft.[39] Thus even at the close of the 17th century, the telescope as a device for measurement was not completely settled. Allen is right when he says that the seventeenth century ideas were brought to perfection in the following two centuries by time and industrial revolution.[40]

Keeping this historical perspective in mind, can we question Jai Singh (who was primarily schooled in the West-Central Asian and Indian astronomy) for not readily accepting the telescope as a measuring device?

Let us note that Jai Singh was also motivated to build huge masonary instruments at his observatories due to exactly the same afore-mentioned defects in the metal or wooden instruments of West-Central Asian school of astronomy, viz. warping, bending, swelling etc., and because of the most important problems of mounting and stability. By employing masonary instruments—his wall-quadrant was of 20 ft radius and gnomon with the vertical height of about 90 ft-he tried to increase his accuracy considerably. It is therefore quite plausible to assume that he rejected the use of telescope as a measuring device on *scientific grounds* quite objectively because of the type of the telescopes available to him.[41]

The Planetary System

It may also be pointed out that Jai Singh's reception of European astronomy was not confined to just the use of telescope, but he also accepted the European emphasis on observations. Consequently he matched the observations *(marṣūd)* with theory *(maḥsūb)* in contrast to his predecessors. It was thus found by Jai Singh's astronomers that the orbits of the Sun and Moon were ellipses. But he does not state anywhere that the same was true for other planets. Thereafter Jai Singh dealt in ZMS the geometry of the ellipse in detail.[42] However he stuck to the geo-centric model of the planetary motion despite his elliptical orbits.[43]

It may be asked why Jai Singh did not use heliocentric system when Johan Raptist Hoemann's *Grosser Atlas uber die gazne Welt* (Nurenberg, 1725) was available to him. The date of acquisition of this Atlas is 1730, the year when his delegates returned from Portugal. The Atlas, still extant at Jaipur, contains charts on the planetary system of Copernicus (chart 10) and Tycho Brahe (chart 13); the Egyptian and Riccoli systems are also drawn in the margin of chart 13. Thus the heliocentric and geo-heliocentric systems should have been known to him. And yet he completely ignored it. Has his inability to appreciate or accept the new heliocentric system any parallel in Europe, say in the 16th century? The answer is in affirmative.

It has been shown by Schofield that prior to the establishment of Tychonic system (in 1588) a number of attempts were made in favour of geo-heliocentric systems, viz. by Erasmus Rheinhold (1511-53), Albert Konicerus (died 1614) and Christopher Rothmann (16th c.) On the other hand, no less than any great scholar of his times, the French mathematician Francois Viete (1540-1603) modified Ptolemaic model by replacing "some epicycles and deferents by epi-ellipses and elliptical deferents" [44] As a matter of fact the use of the latter specifically "as a kind of oval" is known to have been invented already by Al-Zarqālī (1029) in 11th century and employed in 15th century Europe by the expert of Arabic-Islam astronomy George Peuerbach (1423-61).[45] In this connection we may also recall the opinion of Dijksterhuis that the "introduction of the helio-centric world picture as such could not lead to greater accuracy of the planetary tables."[46] It is therefore not surprising that "no textbook widely used in Europe in the 16th century expounded Copernicus theory and few even mentioned it."[47]

If in the continent of Copernicus (1473-1543) "in the sixteenth century itself.... the effect of his achievement.... was only slight and it did not begin to assume a clearer form until about 50 years after his death."[48] how could one *censure* Jai Singh for not accepting the heliocentric system just by Jesuits' hearing if at all.[49] As in the context of the 16th century Europe, "immediate acceptance of Copernican system is simply an unwarranted expectation by us today",[50] so also should be the case with the reception of Copernican system in the 18th century context of Central West Asian and Indian astronomy.

EUROPEAN ASTRONOMY IN INDIA DURING 17th—19th CENTURIES

With the invention of the telescope in Holland sometime around 1608, its utilization by Galileo in 1610 for astronomical observations and its development later as a measuring device, European astronomy developed in the 17th century quite on practical lines. That is, it was purely positional astronomy, in which both optical telescopes and mechanical clocks (or chronometers) were used as main instruments. The dissemination of that astronomy into India appears to have taken place in three stages:[51]

(i) Astronomical observations of heavenly bodies by individuals, especially by the Jesuit astronomers and cartographers;
(ii) Organized efforts leading to planned systematic astronomical observations; and
(iii) Establishment of astronomical observatories.

In this section we show that apart from individual efforts, the systematic astronomical observations initiated at the close of the 18th century led to the establishment of a number of astronomical observatories in several famous Indian cities: Madras, Calcutta, Lucknow, Trivandrum, and Poona. Excellent astronomical work comparable to that of any 19th century European observatory was done at these Indian observatories.

European Background

During 15th—18th centuries, astronomy was developed in Europe not only as a pure science, but more so on practical lines.[52] The great age of European exploration of the four continents began in about the later half of the 15th century.[53] Portugal and Spain were the first to become maritime powers. We may recall here, for instance, the voyages of Columbus to America in 1492—93 and of Vasco Da Gama to India in 1498. Thus navigation and geography progressed hand in hand. The requirements of that age were land maps, maps of harbours, coasts and islands. Beginning with the use of magnetic compess, the mariners and also cartographers employed astronomical quadrants for the measurement of geographical latitude, followed by sextants, and telescopes in conjunction with chronometers[54] to measure both latitudes and longitudes in the 17/18th centuries. Already in the 16th century, cartography was boosted commercially in almost all European countries. Map production, rather printing by employing copper plates engravings, became then a big business in Europe. The following account may to noted,[55]

> "Queen Elizabeth saw a wave of enthusiasm for discovery sweep over England, rousing sailors, soldiers, merchants, persons, philosophers, poets and politicians to vie with each other in promoting expeditions overseas for the glory of their country and their own fame and profit. The gallants of the *courts were ready to command the expeditions for which the shrewd city merchants found the means......*"

It is also told that the "European market was full of printed charts, sea atlases, globes, wall maps, towns plans, views and above all atlas maps".[56] It is therefore natural that commerce and navigation reinforced each other in the 17/18th century Europe. However for good mapping one required accurate geographical coordinates: the latitude and longitude,[57] which were determined astronomically by the observations of Sun, Moon and satellites of Jupiter. What was required then was in fact, accurate astronomical tables/charts for the motion of Sun and Moon, and star catalogues. That was impossible without the establishment of observatories and their governmental sponsorship;

> "In the seventeenth century astronomy began to be a government affair. Formerly in Tycho's time, princes had often endowed astronomical pursuits, which were personal hobbies of single individuals.
> In the next century, under royal absolutism, astronomy, besides being a personal scientific activity of a class of wealthy enlightened citizens,[58] eager of knowledge, also took the form of state employment. The practical application of astronomy to the needs of navigation and geography induced the rulers to found observatories."[59]

In that socio-political context the observatories at Paris (commissioned in 1667 and at Greenwich (1675) were established under the royal patronage.[60] The character and nature of work at the two observatories were somewhat relatively different. While at Paris, the astronomers were pursuing the science of astronomy, the objective and aim at Greenwich were geared practically to navigation. However this emphasis of work was not followed very rigidly. For instance, Paris Observatory sponsored one expedition to measure meridian arc-length of 1° near equator, and another for precise determination of solar parallax (i.e. Sun-Earth distance) by observing the transit of Venus in 1761 and 1769.[61]

Finally we may mention that further advances, particularly, in the construction of telescopes were realized by refinements in optical techniques which in turn weie implimented by the industrial revolution in the second half of the 18th century England[62] [63] The technical basis and progress in astronomy, geography, cartography and navigation was then assured by the rise of big industry in 19th century Europe, a factor completely missing then in India and playing only now in independent India its pivotal role!

The Jesuit Contributions

The Indian Situation

In the context of the development of cartography and practical astronomy in 16/17th century Europe as briefly outlined above, it is not surprising that the Jesuits who came to India and even went as far as China or Japan were learned men, particularly trained in the art of geography/cartography and therefore practical astronomy.[64] As a matter of fact they were first Europeans to introduce modern Western astronomy into South and South-East Asia, when the Church dropped gradually the initial opposition to post-Copernican telescopic astronomy. Alternatively, it was also then hoped that the "European art and sciences (like mathematics, mechanics, astronomy, painting, music, medicine) were the only support which could prop the very weak and slow propagation of Christianity, besides winning the monarch's favour and goodwill for Christians, particularly his conviction for Christianity."[65]

After the colonization of Goa in 1510, its consolidation in the following decades and the establishment of the Jesuit order in 1534 by Pope, John III of Portugal requested the Pope to establish a Jesuit mission in India. A group of Jesuits headed by St. Franci's Xavier set out in 1541 to establish a mission in Goa, which was then extended to Travancore Cochin by 1533.[66] In any case a multitude of missions by Jesuits and by other Catholic orders and countries (like French, Dutch, German and quite late in 1833 by English) were founded throughout the length and breadth of India.[67] That those Jesuits involved themselves in many academic and/or missionary activities is not our concern here.[68] We are here interested only in their astronomical observations and therefore in the sequal we deal briefly with the most important Jesuit cartographers cum astronomers who became quite popular at the courts of Mughal emperors and local rulers.

As early as 1568, the fame of the Jesuits' scholarship reached the court of Emperor Akbar (1542-1605) who requested the viceroy at Goa to send missionaries to his court. Father Anthony Monserrate (1536-1600) was one of the members of the first Jesuit mission to the court of the Mughal Emperor.[69] The Jesuit determined geographical coordinates of about hundred positions on his way from Fatehpursikri to Kabul, while accompanying Akbar in 1580/81. It is not widely known that Monserrate was the first foreigner to compile a map of India c. 1590. It was a small map but "partly based on measured routes and astronomical observations.... though it is seriously out in longitude".[70]

Father Jean-Venant Bouchet (1655-1732) went to Pondicherry in 1689 where he is reported to have carried out astronomical observations for the sake of surveying the peninsula, particularly determining the geographical positions in 1719 along the Madras coasts. His map of the interior was "the first map of any merit", dated 1722.[71] The cartographical work of Father Bouchet was utilized by D'Anville (1697-1782) in his "*Carte de Cote de Coromandel,* (published in Paris 1753, in London 1754).[72]

Father J. Richaud (1633-1693) was already a well-known astronomer when as a member of the French embassy he left for Siam in 1687 "as mathematician of France". The title was bestowed upon him by Louis XIV. From Siam he came along with Bouchet to Pondicherry in 1689, where he set up his 12-ft telescope. His most significant observations were; (1) the comet of December, 1689; (2) binary nature of *alpha-Centauri* and alpha-Cruis; (3) exact prediction of the occurence of lunar eclipse of April 4, 1689, (4) latitude and longitude of Pondicherry and that of Mylapore (San Thome); (5) zodiacal lights at Pondicherry in 1690; and (6) the Megallanic Clouds and two dark clouds towards Coalsack. Besides carrying on astronomical observations he also taught astronomy at the Jesuit school, then started at Mylapore.[73]

The most well-known astronomer-cartographer was the French Jesuit Claude Stanisla Boudier (1687-1757 at Chandarnagore) who became so much reputed as an astronomer that Maharaja Jai Singh II invited him in 1734 to take observations at Jaipur. During the course of his journey, Boudier determined both latitudes and longitudes of 63 Indian cities in 1734, and also meridional altitudes of a few stars.[74] We mention below some of Boudier's observations to determine the longitude of various places;[75] (1) observation of the first satellite of Jupiter, on April 2, 1734 at Fatahpur; again at Jaipur on August 15, 1734; (2) solar eclipse of May 3, 1734, at Delhi; and (3) lunar eclipse of Dec. 1, 1732.

Boudier was in constant touch with Father Gaubil at Peking, whose simultaneous observations he utilized in his calculation for difference of longitudes; for this purpos he used also Cassini's observations at Paris. He also possessed La Hire's table (edition of 1702). It may also be mentioned that Boudier used a watch and a 17 ft long telescope,[76] and an aperture gnomon.[77]

Besides the meridional altitudes of a few stars, Boudier carried out observations/calculations for the length of the year, the diameter of the sun, the obliquity of the ecliptic and its variation.[78] However, Father Gaubil considered value of the diameter of the Sun as over estimated. In fact Gaubil critized Boudier as follows :

> "It is several years since I received any thing from Father Boudier. He has, undoubtedly, sent every thing to Paris. Hower, I have a good part of what he did, till 1738 and 1739; and I find that he is much mistaken with respect to the diameter of the Sun and the obliquity of the ecliptic. I do not know whether the right ascensions of the stars are very exact. He had not then any knowledge of the oberration of the stars.[79]

Nevertheless he appreciated Boudier's determination of geographical coordinates: "His (Boudier) journey from Bengal to Agra, Delhi etc. along with observations inform us at last the true position of Delhi and Agra."[80] Both D'anville and Tieffenthaler had utilized Boudier's values of latitude and longitude extensively.[81] According to D'anville Boudier was "Très habile dans l' Astronomie, qu'il a cultivée par inclination."[82]

For the sake of completeness we may mention here the Portuguese Superior of Jesuit Father Emmanuel de Figueredo (1690?—1753?) who came into contact with Raja Jai Singh II about 1729 and reported to him the "grand progress in astronomy achieved in Portugal."[83] As a result, Figueredo went to Portuguese king Don Juad V, as head of an embassy of Jai Singh, in 1730 and returned to India with a number of European works, especially Phillipe de La Hire's astronomical tables (edition 1702).[84]

In passing we may also mention the Portuguese Father Xavier de Silva,[85] the German Father Cabelsberger[86] (1704-1741, died at Jaipur) and Strobel[87] (1703- who assisted Maharaja Jai Singh in his mathematical astronomical activities. About father Jean Calmette, (1725-1740 in India) with whom Jai Singh corresponded to on his doubts regarding the underlying geometrical model of the astronomical tables of La Hire, it is known that his value of obliquity was different from that of La Hire and that he was primarily engaged in determining geographical positions for a map of South India.[88]

Finally we shall like to conclude this section by giving a brief account of Father Joseph Tieffenthaler (1710-1785) who came to India in 1740, and died at Lucknow.[89] Tieffenthaler became famous especially for his *Historical and Geographical Account of Hindustan,* published both in German and French (see the bibliography).[90] In fact, as an excellent cartographer/geographer, he was engaged in several astronomical observations with which we are particularly concerned here They are:[91]

(1) Meridian altitude of the Sun at various Indian cities of India for the determination of latitudes.

(2) Solar and lunar eclipses,

(3) Jupiter's occultation by Moon on Feb. 2, 1744 at Surat, and also immersion and emersion of its satellites.

(4) Transit of Mercury on Nov. 4, 1743 at 2 P.M. in Goa. He described the planet a glowing coal across the solar disc" and lamented his inability to observe the beginning and the end of the phenomenon for want of astronomical instruments, and making his observation useless for astronomy.[92] In fact, Tieffenthaler mention in his geographical work at various places the astronomical instruments at his disposal, namely, astronomical quadrant of brass and astrolabe.[93] Most probably he could also use the instruments at Jai Singh's observatories at Delhi, Jaipur, Ujjain, Benaras and Mathura, on which he reported fairly well.[94]

In comparison with his Jesuit predecessors, Tieffenthaler seems to us an excellent scholar, quite familiar with the post-renaissance European astronomy as well as oriental astronomy. This is apparent from his various references to Latin works (more precisely Latin translations of Arabic works) and from his allusion to the original work of 'Abd Al-Raḥmān Sufī (903-983), the astronomical tables of Naṣīruddīn Al-Ṭusī (1201-1274) and of Ulugh Beg (1394-1449)[95]. Besides he wrote in Latin a monograph on Indian astronomy and astrology.[96]

A Parallel Situation in China

We would like to digress here to a parallel situation in China regarding Jesuit contribution in order to draw certain conclusions for the Indian situation. A number of prominent mathematician-astronomers went to China during 16—18th centuries and took part in the promotion of mathematical astronomy, in particular. The most important who wrote in Chinese were : Metteo Ricci (in China 1583-1610), Joh. Schreck[97] (arrived in 1618) Adam Schall Von Bell,[98] F. Verbiest[99], I. Kogl[100] and A. Von Hallerstein.[101] Their importance can be gauged from their academic background and/or contact with the European scholars of 17th century. Ricci had been a student of and became later a friend of Christopher Clavius;[102] Schreck (*alias* Terrentius) was in active correspondence with Galileo and Kepler. In fact he knew both of them personally. Kepler sent him in 1627 even Rudolphine Tables. He even brought a telescope with him and presented it to the Chinese emperor in 1634.[103] On the other hand, Schall was inspired in his youth by telescopic discoveries of Galileo.[204] And Kogler was quite well familiar with the observational work of Flamsteed and Cassini.[105] In a way therefore it is not surprising that the following remarkable works on calendarical/astronomical sciences were written by those knowledgable scholars *in Chinese*:[106]

(i) *Ricci Corpus,* part II comprises two works on astronomical and calendar calculation/theory and five works on astronomical techniques, written during (1607-1632).[107]

(ii) *Brief Description of the Measurment of Heavens* (1628) in which, without naming Galileo, Schreck mentioned the Sunspots and the phases of Venus; "it being a satellite of the Sun".[108]

(iii) *The Far-seeing Optik Glass* (1626), a treatise on telescope by Adam Schall, in which again Galileo's name was not mentioned. The same was the case in Diaz's book *Explicatio Sphaera* (1615) where telescope and Galileo's discoveries were given for the first time.[109] As a matter of fact only in 1640 with the publication of Schall's *History of Western Astronomy,* the names of Galileo, Tycho Brahe, Copernicus and Kepler appeared in Chinese.[110] However, Schall in his *Encyclopaedia on Astronomical and Calendric Sciences* follows basically Tychonic system and "no direct discussion of Copernicus' heliocentric theory is given in his encyclopaedia."[111]

(iv) Lastly we may also recall the afore-mentioned[112]: [88]*Sequel to the Compendium of Observational and Computational Astronomy* (1742), by Ignatius Kogler and his assistant Andrew Pereira, in which though "improved constants and tables based on the observations of Cassini and Flamsteed" were incorporated along with Keplerian ellipses, yet the *model of the planetary motion was actually Tychonic.*"[113]

Let us conclude this digression in the words of the famous historian of Chinese Science N. Sivin: Nontheless,[114] sixteen years after the death of Newton thirteen years after the announcement of Bradley's discovery of stellar aberration, heliocentrism was still anathema in China. It was Kepler's old master Tycho Brahe furnished the scenery. The Earth was static,......while the Sun and Moon rode about the Earth on ellipses, the planets were still making their rounds of the Sun on the cranky epicycles of Tycho,[115]

We have discussed at length the Jesuits astronomical work in order that one could differenciate the Chinese vis-a-vis Indian situation during the 17—18th centuries.[116] First not a single treatise or monograph on Western science in Persian or Sanskrit written by Jesuit scholars working in India is known to-date, excepting a stray reference to the Persian translation of Gassendi's and Descartes philosophies.[117] Second, obviously the early Jesuits in China as well as in India, like members of other orders: Dominicans, Franciscans etc., wished to preach primarily the Gospel[118] and their strategy was to convert the elite (Emperors, Rajas and high officials) so as to achieve wholesale conversion. However in China the Jesuits "desired to convince the Chinese of the superiority of Western religion by demonstrating the superiority of Western Science in their day and age"[119] for example, correct prediction of eclipses etc. As a result a huge production of literature on modern science or astronomy in Chinese language was achieved. On the other hand, that kind of motivation was not at all required by the Jesuits in India, since for instance Emperor Akbar (1556-1605) invited thrice for disputations Christian missions from Goa to his court, namely in 1580, 1591 and 1595; Jahangir (1605-27) is also said to have protected the missions.[120] Third, barring a couple of them like Boudier and Tieffenthaler, the Jesuits in India were mostly no good astronomers or scientists; they were also not in correspondence with the best European astronomers in contrast to those in China as mentioned above.

Finally we may note that despite all that afore-mentioned astronomical literature in Chinese, the introduction of Copernicus, heliocentric system *was withhold* by the Jesuits till the removal of his work *De Revolutionibus* (already published in 1543) from the list of banned books by the Catholic Church in 1757. Only in 1760 the famous Jesuit astronomer M. Benoist (1715-1774) could venture to explain the Copernicus' world system in his work.[121] However, in India the year 1757 was a crucial one, when the battle of Plassey took place and by 1765 the East India Company (EICo) had gained virtual control of the whole of Bengal. The acceleration of the decline of Mughal empire thereafter generated a political chaos in which the transfer of European science could not serve the Jesuits' main purpose of proselytization in anyway. From then onwards all political and also scientific activity in India passed into the hands of EICo; we discuss the latter in the following sections. In passing we may add that in the last decade of 18th and throughout 19th century, despite the political turmoil and instability in the country, several Indians attempted to contribute themselves to the transmission of European astronomy.[122]

The Beginning of Organized Efforts

With the commencement of the age of world-wide exploration in the 15th century and its further growth during 16—17 centuries, an era of European armed colonization began in the Afro-Asian countries, in order that their natural resources could be exploited by European powers for commerce, trade and capital accumulation in particular. As a result the Indian sub-continent was also teaming with colonial powers: Portuguese, Dutch, French and English. The East India Company (EICo), founded in 1599 for the promotion of trade between England and the East, could establish its first factory and warehouse at Surat (on the West Coast of India) in 1608, and later more factories at Madras, Bombay and Calcutta. The strategy of EICo, to promote trade not only with diplomacy but also by wars and finally by full control of the territory, bore excellent "fruits". In the unstable socio-political atmosphere during 17—18th centuries, when the Mughal power declined and the then Indian empire started to disintegrate, a clever exploitation of author by EICo gave rise to a rapid ascendency of the Company to paramountcy. It has already been mentioned that in 1757 the battle of Plassey had been quite decisive. By 1765 the whole of Bengal (including Bihar) was under the virtual control of EICo. In fact the Company was also successful in driving out from South India the French (after three consecutive Carnatic Wars during 1746-1763), gaining control of the Madras Presidency, confining the French influence to Pondiehcrry only and in bringing under its control also Nawabs of Mysore and Nizams of Hyderabad in the last decade of the 18th century. Thus at the beginning of the 19th century EICo was to be reckoned as the imperial authority in nearly three-fourth of the sub-continent.[133]

For the sake of gaining knowledge of the Indian Sub-Continent and its natural resources, establishing an efficient communication network and particularly for revenue purpose, EICo started its geographical surveys quite systematically, already in the sixties of the 18th century. It may be recalled that the earlier map of India by D'Anville & J. Rennel (1742-1830)[124] were based largely on geographical tables of Ptolomy (fl. 150 A.D.), Naṣīruddīn Al-Ṭusī (13th c.), Ulugh Beg (15th c.) and of the Indian scholar Abul Faḍl as given in his *Ā'in-i Akbarī* (16th c.).[125] But since these tables were not accurate enough and by no means were based on systematic astronomical observations, the cartography in India was especially promoted by EICo, with the aid of its own surveyors. Mention may be made here of the works of the following personalities who emphasized the astronomical observations in particular.

Rev. W. Smith (c. 1775 in Bengal) carried out astronomical observations "for the sake of amusement and to help the cause of geography."[126] Employing a Dolland telescope of 3½ ft. with a triple objective furnished with micrometer and also a quadrant, Smith determined the longitude of places by standard methods; eclipse of Jovian satellite, occultation of stars by Moon and latitude from meridional altitude of stars. Smith left "55 large folios" of astronomical observations. The accuracy of his geographical work was appreciated even by Rennel.[127]

Smith sold his instruments to J. D. Pearse (1741-1780), a commander of artillary and such a keen regular observer of astronomical/meteorological phenomena that he took observations during marches of Mysore War.[128] Besides using Smith's instruments, he employed also a 18″ quadrant and a sextant of 6″ radius, made by Ramsden. Many of his cartographic and astronomical observations were published in *Asiatic Researches* and a good number of them (carried out during 1778-1781) on board the ship "Bengal" are said to be still extant in the Library of the British Museum. Pearse was a personal friend of Governer General Warren Hastings, was in correspondence with Astronomer Royal N. Maskelyne and Sir Robert Barker and supported whole-heartedly Burrow's astronomical survey plan of 1787.[129]

We have already described briefly the European age of world exploration which boosted evidently the map-making business during 17-18th century Europe. The science of cartography is primarily based on the determination of geographical coordinates—the latitude and longitude. However, the problem of determining the longitude at high seas for accurate navigation took an unusually long time to solve, i.e. till the chronometer method was invented.[130] The importance, rather urgency of that problem can be appreciated by the fact that "a petition by sea-captains and London merchants to provide a public reward for the discovery of (a good method to determine) longitude at sea" was presented to the British Government. To that end a bill for the following rewards was passed in 1714 by the British Parliament:[131]

(i) £ 10 000 for a method with an accuracy of 1°, corresponding to 60 nautical miles;

(ii) £ 15 000, for an accuracy of (2/3) degree, corresponding to 40 nautical miles;

(iii) £ 20 000 for an accuracy of ½°, corresponding to 30 nautical miles.

To assess the various individual claims, a Board of Longitude consisting of 22 members was also constituted. For instance, one of the members of that Board was E. Halley (1656-1742), famous for his comet of 76 years' period. The problem of determination of longitude was in fact so important[132] that even the observations of rare phenomena like transits of Mercury and Venus were suggested, already in 1691 by no less than Halley himself.[133] In particular, the transits of Venus of June 6, 1761 and June 3, 1769 were proposed for the world-wide observations, because of their long duration of about seven hours.[134]

The Royal Society at London (founded in 1662) was interested from its earlier years in accurate navigation. On the request of the Society the Directors of the EICo decided to organize in a planned way the observations of the two transits.[135] The directors even declared in 1768 that such observations "will afford the only means of ascertaining some principle and hitherto unknown elements in astronomy and of improving both geography and navigation......"[136] To that end, the following instruments were imported officially into India: (i) a reflecting telescope of 2 ft. focus, (ii) a pendulumn clock, and (iii) an astronomical quadrant of 1 ft. radius.[137]

A number of EICo's engineers succeeded in observing the transits of Venus: From the observation of B. Plaisted (d. 1767) at Chittagong, the Astronomer Royal deduced the longitude of Islamabad as 91° 45'; Rev. W. Hirst (d. 1770) observed it at Madras in 1761; L. F. De Gloss (in India 1753-1774) at Dinapore, J. Call (1732-1801) didn't succeed because of cloudy weather. The same bad luck was met by the Frenchman Guillaume Le Gentil De La Galaisiere (1725-1792), who was sent by the Academie Royal des Science (Paris) for observing the transits. In 1761, he arrived in India late, after the expiry of the phenomenon. For the transit of 1769, EICo put at his disposal the best telescope of Madras. But for the clouds which obscured the Sun during the occurrence of the transit he could not realize his ambition for which he waited in the Indian Ocean for 8 years. However, between 1761-1771 Le Gentil surveyed the environ of Pondicherry for latitude and longitude by observing eclipses of the Moon and satellites of Jupiter, also lunar hour-angle. He compiled a table of refraction, determined the length of second's pendulum and carried out magnetic measurements in the South Indian Ocean.[138]

Finally we must mention the notable astronomer R. Burrow (1747-1792) who was the first to emphasize the extreme importance of founding the Indian geographical surveys on *regular* astronomical observations.[139] As the most talented astronomer, at one time assistant of Astronomer Royal, N. Maskeylyne and astronomy teacher for engineers at Fort William (Calcutta), Burrow took part in many geographical explorations. "Notable", as he was, "for his effort to break away from the common place", he criticized severely the method of surveying in India by EICo:[140] "Geography is so little benefitted by such maps (i.e. the English ones) that they are a nuisance rather than advantage, and there is no other proper method of correcting such surveys but by determining the positions of some of the most material points by astronomical observations". Thus Burrow recommended a regular astronomical survey, also some physical observations,[141] emphasized "on precise determination of actual and relative positions"[142] of places, and even *an astronomical observatory* for India in order "to make corresponding observations with the aid of a 4 ft. reflecting telescope, a theodolite made by Ramsden, a sextant of 6" radius made by Troughton and an Arnold's chronometer, Burrow carried out extensive astronomical observations particularly during 1790-91.[143] After his death his observation on reduction led to the following values for one degree of longitude (at 23° 28' N) and latitude as 55989 fathoms and 60457 fathoms respectively.[144] It has been assessed that his observations "were of a far higher standard than are hitherto taken in India and for the next 30 years (were) accepted as the best available....[145] In favour of his genius for astronomy, one may cite the information that he mastered Sanskrit for translations of old manuscripts, wrote astronomical notes in Galdwin's translation of Abul Faḍl's *Ā'īn-i Akbarī*, and recommended the use of large quadrant at Banaras Observatory.[146]

We may conclude this section by adding that his efforts led to the regular astronomical control of geographical surveying, thus indirectly supporting modern astronomical activities on Indian soil.[147] As an example we may quote the sailor-surveyor Michael Topping (1746-1796) who observed with a Dolland's telescope in 1785 eclipses of satellites of Jupiter in order to determine longitudes in the Maldive Island, and utilized also his 55 meridional observations of fixed stars to ascertain with exactness the latitude of the Company's House at Coringa Bay.[148] In the following section we deal briefly with Topping who in fact was the *driving force fer getting the first modern Western Observatory established in India* at Madras in 1792. He took the Board of Directors of EICo at their word and pleaded: "Astronomy has ever been acknowledged as the Parent and Nurse of Navigation and it is doubtless from considerations of this nature that the Hon'ble Court have come to the resolution of thus affording their support to a Science to which they are indebted for a rich and extensive empire."[149]

THE ESTABLISHMENT OF OBSERVATORIES

Since the development of astronomical knowledge is closely related with the establishment of observatories we go over to their foundation by EICo and also by Indian monarchs. In particular we relate their origin, growth and astronomical work performed there by various astronomers/directors whose brief biographical sketch and conditions of work then are also narrated. Finally we list the astronomical instrumentation employed at those observatories from time to time, which in turn reflects directly the standard of astronomical activity. Wherever possible a glimpse of the scientific outlook of the astronomers working then in India is also given.

According to our present knowledge, the following modern observatories were established in Indian during 18-19th centuries.[150]

1. Madras Observatory (1792);
2. Calcutta Observatory (1825);
3. Royal Observatory at Lucknow (1835);
4. Raja of Travancore Observatory at Trivandrum (1837);
5. Poona Observatory (1842);
6. St. Xavier's College Observatory at Calcutta (1875);
7. Maharaja Takhtasingji Observatory at Poona (1882);

8. Hennessy and Haig Observatories at Dehra Dun (1884, 1886);
9. Presidency College Observatory at Calcutta (1900).

It should be mentioned at the outset that all other observatories except the Madras Observatory were either abolished or later stopped astronomical work altogether. In the last section of this contribution we dwell upon briefly the reasons for that state of affairs.

The Old Madras Observatory

The history of this famous observatory established by the East India Company has been treated in a number of works, [151] [152] [153] and therefore we recall in the following its origin and establishment only briefly.

Michael Topping (1747-1796).

The only sailor-astronomer of all the surveyors stationed at Madras, Topping came to India in 1785, when he engaged himself in the determination of longitudes in the Maldive islands and in Ceylon.[154] In 1787 he was engaged in coastal surveys north of Masulipatam[155] and "southward to Cape Comorin......(to) ascertain the position of the principal places in Carnatic."[156] He utilized for that purpose "an excellent instrument on the Hadlean principle" by Stancliffe, an artificial horizon and telescope by Dolland, also on Arnold's chronometer. He employed the satellites of Jupiter for longitude determination, for latitude used his meridional observations of fixed stars.[157] By 1788 he completed his chart of the Coringa Bay. [158]

In 1789 Topping suggested to the Madras Government to acquire the private astronomical observatory of William Petrie[159] who, while departing for England, then, "offered his instruments as a gift to the Government". Topping argued:" 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 persons to render them serviceable had been scattered abroad in different parts of the country."[160] He then listed the following instruments: (i) 2 astronomical quadrants, one by Bird, (ii) 2 acromatic telescopes with a triple object glass by Dolland, (ii) 2 astronomical clocks with compound pendulum, (iv) time-keepers by Shelton, and (v) transit instrument presented by Petrie.

To start with, Topping thus floated the idea of a *depository* erected for Petrie and Company's instruments, so as to protect the instruments" from the hazard of injury and usage, if not total demolition....".[161] He also praised the EICo for his efforts to support scientific work, as quoted in the preceding section. In 1790, the Directors of EICo agreed that "the Establishment of an Observatory at Madras would be very great advantage to science,"[162] and after two years during the Governorship of Sir Charles Dakeley, he was appointed the first Director of the Madras Observatory, with John Goldincham as his assistant,[163] and later by an Indian.[164]

Already in 1791 the house of one Edward Garrow was used by Topping for his instrument and office. By 1792, the observatory was erected.[165] Topping describes in detail in his report the building plan of the observatory. We confine here however to the remark that granite pillars or foundation-towers were constructed to keep the instruments free of vibrations, one each for mural arch or circular instruments for taking meridian altitude, for the instrument for taking equal altitude observations and for the transit instrument by Stancliffe. The remains of these pillars are still extant at Madras.[166]

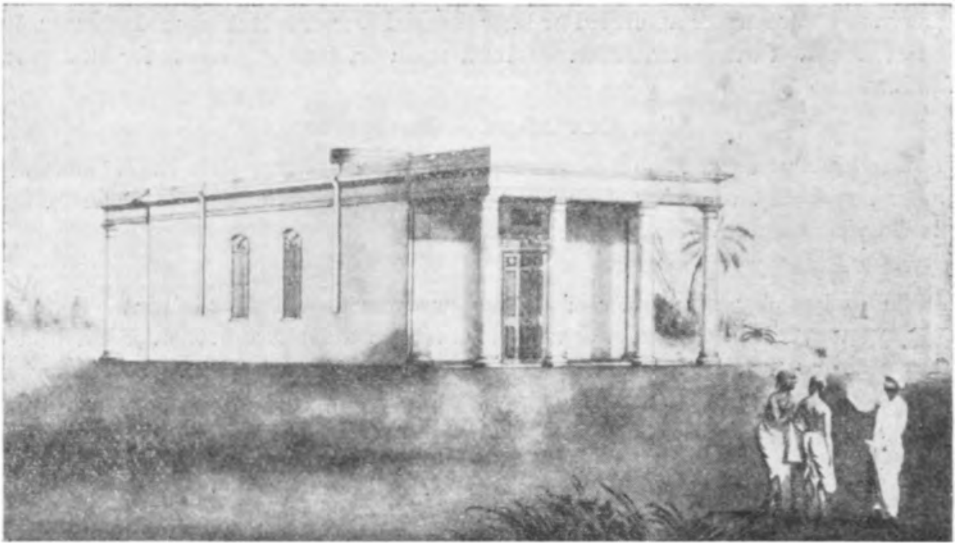

Fig. 12.1. Madras Observatory

As a person of very considerable mathematical and geographical knowledge[167] he knew very well that," every correct observation made at Madras that has a corresponding one with which to compare it, taken under any meridian, determines at once the relative longitudes of the two places". In fact Topping was convinced that the "astronomical observations (were)....the only sure and practical method of finding the relative position of distant trans-marine situations" and he hoped for "the chart of these Eastern Seas in a more correct state than those even of Europe....or at least a regular system established for the perfection of Indian Geography."[168]

John Goldingham (*d.* 1849)

Topping was succeeded by the Dane John Goldingham who had assisted W. Petrie at his private observatory before becoming an assistant of Topping. He held the post of Government astronomer from 1796 to 1830. During his tenure he equipped the observatory with a circular instrument of 15″ diameter made by Troughton and also with a vertical and horizontal circle.[169] Moreover, one portable transit by Ramsden, two more astronomical clocks and Dolland's telescopes were acquired.[170]

Goldingham's astronomical observations were published in four volumes. His work comprised mainly the observations of transits and zenith distances of heavenly bodies, solar and lunar eclipses, satellites of Jupiter and lunar occultations of fixed stars.[171] He also performed valuable pendulum measurements near the equator and at Madras, observations of the velocity of sound, and kept a meteorological register since 1796.[172]

To appreciate Goldingham's scientific outlook we quote from one of his communications to the first Surveyor General of India, Golin Mackenzie (1754-1821):

> "....A Public observatory..is an establishment for observing the heavenly bodies to ascertain their exact positions and motions with a view to the improvement of the tables and geography and navigation..Most enlightened princes have been proud to have such establishments in their dominions as, independent of their utility to science and navigation, none lead to discoveries so sublime regarding the widsom, power and goodness of the Deity; they also become a sort of focus for real science to emanate from."[173]

Goldingham's notable contribution to geography is said to be his determination of the longitude of his Observatory as 80° 18′ 54″. Some of his researches were published in *Asiatic Researches.* It may also be mentioned that a number of Indians assisted him in his daily observational programme, namely transit of Sun and of a number of stars in order to regulate the astronomical clock.[174]

Thomas Glanville Taylor (1804-1848)

Taylor who succeeded Goldingham was recommended in 1830 by none other than the Astronomer Royal John Pond. Taylor had worked as incharge of night transit observations at the Royal Observatory since 1822.[175] On his joining the duty at Madras he made it his first task to put up new powerful instruments: a 5 feet transit, a mural circle of 4 feet in diameter and a 5 feet equatorial by Dolland.

The greatest work which Taylor turned out during his 18 years cf service as Government astronomer was the compilation of his fixed star catalogue, which was finally published in 1844 as the *Madras General Catalogue of* 11015 *Stars.*[176] The significance of his work in general and especially of the afore-mentioned catalogue can be appreciated by the report of the Royal Astronomical Society in which it was stated:

> "In the execution of....(the Society's catalogue of stars)....considerable assistance has been afforded by the....catalogues published by Mr. Thomas Glanville Taylor at Madras. The second of these catalogues contains nearly all the stars in the Society's catalogue visible in that latitude and the last two exhaust nearly the whole of Piazzi's celebrated catalogue....The establishment of this observatory is highly honourable to the East India Company and the fruits which it has produced reflect great credit on the zeal, assiduity of Mr. Taylor, the active superintendent".[177]

Even after ten years of its publication Sir George Airy characterized Taylor catalogue as "the greatest catalogue of modern times". And according to Madler, Taylor's observations were "comparable in value to those of Dr. James Bradley and as the first satisfactory accuracy made within the tropics."[178] The highest recognition of his work was his election as a Fellow of the Royal Society in 1842; he was also a Fellow of the Royal Astronomical Society. Besides his stellar work, Taylor also observed Halley's comet of 1836 and that of Wilmot's of 1845. He is said to have accumulated extensive meteorological and magnetic data at Madras.[179]

William Stephen Jacob (1813-1862)

In Dec. 1848 W.S. Jocob was appointed as director of the observatory. To the already existing instruments at Madras he added a 6.3″ aperture equatorial constructed by Lerebour in 1850 and a new meridional circle by Simms in 1856.[180]

Jacob supplemented Taylor's star-catalogue by observing 1440 stars, on the basis of which he corrected the value of the proper motion of a group of stars. Already a well-known expert of double stars of his time[181], he continued their observation at Madras and collected data for 250 double stars. He calculated especially the orbit of *alpha-centauri.*

His planetary work consisted of the observation of the then newly found planet Neptune, estimation of elements for the satellites of Saturn and a corrected value for the mass of Jupiter. He even found in 1852 the transparency of Saturn's ring.[182]

James Francis Tennant (1829-1915)

In April 1858 Captain Jacob left for England due to his illness and gave the charge of the observatory temporarily to Major Worster of Madras,[183] who on Oct. 13 1859 relinquished it to Major J. F. Tennant.[184] However, Tennant joined also as a temporary director for the short period of one year only. On resuming charge he immediately consulted the Astronomer Royal Sir George Airy. In a letter dated Oct. 23, 1859 he discussed in detail with Airy constructional improvements in astronomical instruments: transit, equatorial etc., also their stability with the aid of granite pillars, mentioned his proposal of a revolving dome and erection of time-ball "for correcting all of our clocks and chronometers" by transmitting the signal telegraphically. He informed Airy also about a Newtonian reflector of 18½ ft. focal length being then "retrieved by Major Worster at his laisure". Finally he lamented on his receiving irregularly the *Monthly Notices* and *Astronomischen Nachrichten* and pleaded for early transmission of information.[185] Further, after writing a report on Madras observatory, dated June 14, 1860, he resigned his job as Government Astronomer[186] due to financial reasons.[187]

Though Tennant was not connected with the Madras observatory further, yet we would like to describe briefly his astronomical work in India at large, since his work was recognized by his election as Fellow of the Royal Society in 1869, and to Presidentship of Royal Astronomical Society in 1890-1891.[188] His major contribution was actually in the observation of total solar eclipses of Aug. 17-18, 1868 at Guntoor and Sept. 11-12, 1871 at Dodabetta (Nilgari Hills), and also of the transit of Venus in 1874 at Roorkee, employing then the newly discovered technique of photography.[189] From the point of view of the history of astronomy he was the first to ask questions about the physical nature of solar prominences already in 1867, and to report his spectroscopic observations of the coronal continuous spectrum, and of a bright line from the prominence. After supervising the observations of solar eclipse of 1871, he could compile clearly the information about the constitution of the Sun.[190]

Finally, it may also be mentioned that as a sequel to his observations of the transit of Venus, he proposed a solar observatory for Simla, "especially for observations with the spectroscope and by photography and also for the observation of Jupiter's satellites". His proposal, though rejected, "led to the daily photography of the Sun at Dehra Dun".[191]

Norman Robert Pogson (1829-1891)

Early in 1861 Pogson was appointed Director of the observatory on the recommendation of J. Herschel and C. Piazzi Smyth. He held the directorship for 30 years! To the equipment of the observatory he added especially two new instruments: (i) a transit circle of 42 inches in diameter which was read by six miroscopes and a telescope of five inches aperture, constructed by Troughton and Simms, (ii) an equatorial with an 8″ object glass.[192]

Before joining Madras, Pogson had worked at a few British observatories,[193] where he soon became known as a first class observer of variable stars and especially of minor planets. He discovered four of them during 1854-1857,[194] and with seven years of joining Madras he discovered five more planets: *Asia* on April 17, 1861; *Freia* on Feb. 2, 1864; *Sappho* on May 3, 1864; *Sylvia* on May 16, 1866 and *Camilla* on Nov. 17, 1868.[195] During this time he also discovered seven more variable stars and another one in 1877; in fact, he continued at Madras his compilation of a *Variable Star Atlas* which he had started at Radcliffe Observatory (Oxford) in 1852.[196] This work was done with the help of his Indian head-assistant C. Ragoonathchary.[197]

Using the equatorial and meridian circle, in the use of which he was supposed to be one of the topmost experts of his time, he prepared a star catalogue based on 51101 observations, carried out between 1862 and 1887.[198] This catalogue included a number of southern stars between 110° and 150° of North Polar distance which were unknown up to that time.[199]

In Dec. 1872 he claimed to have detected the comet Biela, and during 1862-1873 he took five series of opposition observations of the planet Mars in order to investigate the constant of solar parallax.[200] Besides, he was the first to observe the bright line spectrum of the corona at the time of the total solar eclipse on Aug. 18 1868, which he watched at Masulipatam.

It is said that Pogson had an exhaustive knowledge of the astronomy of his time and as an observer only one or two of his contemporaries could equal him. There is no doubt that his 44 years of astronomical activity proved, in the words of John Herschel, his "conspicuous zeal, devotion to and great success in the science of astronomy."[201] In the history of astronomy he is knowne ven today ast he originator of the so-called 'Pogson's scale' for photometric work. It is the logarithmic scale for the light ratio of stellar magnitudes. Further recognition came to him with his election to Royal Astronomical Society and with is nomination in 1878 as a Companion of the Indian Empire.[202]

C. Ragoonathchari (?—1880)

The first Indian astronomer of the last century who contributed significantly to the Indian astronomy was Chintamanay Ragoonathchary. He was head-assistant at the Madras observatory where he served for 35 years under various directors.

He was a skilled observer, excellent at calculations and possessed a capacity to work very hard, owing to which he could claim to share 38000 observations in the *Madras Catalogue of Stars*. His first paper was submitted to the Royal Astronomical Society as early as 1859 on "The Determination of Personal Equation by Observations of the Projected Image of the Sun". He was the first and only Indian in the last century who discovered two new variable stars: *R. Reticuli* in 1867 and *V. Cephei* in 1878. He also participated in the observations of the total solar eclipses of 1868 and 1871. In January 1872 he was elected a Fellow of the Royal Astronomical Society.[203]

C. Michie Smith

After Pogson's death Michie Smith took charge of the Madras observatory as director up to 1899.[204] Besides completing and publishing the work of Pogson, Michie

Smith tried hard to start "the new Astronomy" in India. In his annual report of 1892 he thus presented his case.[205]

> "During the 33 years which have elapsed since the instruments now in use in the observatory were ordered, astronomy has advanced so rapidly along certain lines that the instrumental equipment is again found very defective....for the "new astronomy"—photography and spectroscopy—there is practically no provision".

The same opinion was also expressed four years later by John Eliot, Meteorological Reporter of the Govt. of India.[206]

By then, as a matter of fact, even the Government of India had "fully recognized the desirability of India cooperating in the important class of observations comprised under the subject of 'Solar Physics' and (had)..sanctioned the erection of a suitable observatory at Kodaikanal"[207] [208] So the foundation of a solar observatory was laid at Kodaikanal in 1895 and its construction was carried out under the supervision of Michie Smith, who acted then as director of both the observatories. By April 1899 the astronomical work at the Madras observatory was confined to mainly meridian observations for time service and some weather forecasting.[209] By the end of 1900 Kodaikanal observatory was completed and started functioning. The programme of work was chalked out by Michie Smith and it was approved by the Observatories Committee of the Royal Society. From then on real organized astrophysics began in India, i.e. at the Kodaikanal Astrophysical Observatory.[210] But its description is beyond the scope of the present article.[211]

To bring this section to an end and to sum up the importance of the Madras Observatory in the last century we would like to quote from the *Memoirs* of Merkham, who wrote in 1878:[212]

> "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 Singh....It has produced results which entitle it to take rank with the observatories of Europe".

Unfortunately within less than 100 years this observatory and the men who worked there have been completely forgotten: In a standard reference work like *Encyclopaedia Britannica* (1966), whereas Jai Singh's observatory at Jaipur is mentioned,[213] there is hardly a single sentence on the history of Madras Observatory and its contribution to the astronomy of the last century.[214]

In conclusion it may be admitted that though the above-mentioned account appears to be quite detailed yet the author is well aware of its shortcoming. A good number of original records are still lying untapped at the Archives of Herstmonceux and Royal Astronomical Society (London). On the basis of some selected ones we intend to treat this topic in detail elsewhere.

Calcutta Observatory

This observatory was established by the East India Company following a proposal by V. Blacker (1778-1826), the Surveyor General of India, to start an astronomical survey of Bengal in order to supplement the surveying by triangulation method. To begin with, the observatory was equipped with[215]

(i) a transit telescope of 5 feet focal length;

(ii) a zenith tube; and
(iii) a Kater's pendulum.

But J. A. Hodgson (1777-1848), one of the first observers who used these instruments had complained: "The instruments..may..be considered as mere playthings so far as making further difficult investigations—in the high science of astronomy.."[216] is concerned. So a few more instruments were later added, namely a transit of 36″ length, an 18″ altitude and azimuth circle and an astronomical telescope of 4½ feet focal length, in order to perform, for instance, eclipse observations. However, as Col. A. Waugh (1810-1878) also pointed out, the "observatory had no pretentions....be considered a metropolitan institution nor was it at all fitted..to investigate questions of high scientific research. It was strictly an *appendage* to the Survey Department...and as such it has fulfilled the object of its institution".[217]

At this observatory Blacker, Hoogsun and a Swiss observer named Vincent Rees performed astronomical observations. An Indian, Sayyid Mir Mohsin (1778-1826) of Arcot in South India was the incharge of instruments. In the words of Sir George Everes, Mohsin had "both genius and originality".[218] A theodolite assembled by him is still preserved at the Victoria Museum, Calcutta.[219]

Hodgson, who was a very keen observer, recorded the eclipses of Jupiter's first satellite and lunar transits.[220] With him, however, the observatory lost its driving force and was then confined only to routine time recording and meteorological observations.[221]

Royal Observatory at Lucknow

The first historical reference to this observatory, which was established in 1832 by King Naṣīruddīn Ḥaydar (who reigned in Oudh 1827-37) is to be found in a report of 1851 of the Royal Astronomical Society (hereafter abbreviated as *RAS*).[222] Thurnton wrote:[223] "Lucknow may be regarded as entitled to an honourable distinction among Indian cities in possessing an observatory".[224] In the historical chronicles following that of Thornton one finds only a very brief reference to the observatory building: *Tārewālī Kothī* ("the star house")[225,226]. Even Markham[227] in his excellent *Surveys* dealt with this observatory by just half a page. Only in 1955 Phillimore[228] gave a few details. His information is mostly based on material published in the journals of Royal Astronomical Society and the Asiatic Society of Bengal.

So far as we know to date, a detailed history of this observatory was written for the first time by us.[229] The historical account of Kamāluddīn Ḥaydrar[230] alias Muḥammad Mīr in Urdu is brief, concerns only with the establishment of the Observatory and is in an old style, i.e. without reference to contemporary source-material; it is rather personal. Our account, both present and previous, is based primarily on unpublished historical records.

Establishment

The observatory, as mentioned above, was established by king Naṣīruddīn Ḥaydar who in 1831 sent the following communication through the Resident of Lucknow to the then Governor General of India, Lord Wiliam Bentnick:[231]

"As my mind is always bent on promoting diverse enlighted arts and sciences which are replete with good and possess salutary advantages to the wise and to the public at large, it is my wish to establish an observatory in the metropolis of Lucknow and to appoint for its superintendence and establishment Capt.

Herbert who from his works and publications professes great experiences in these matters and is eminently skilled and qualified in the knowledge of astronomy......[232] He will receive Rs. 1000 monthly as his pay and Rs. 700 per mensom for the erection of the observatory and carrying its business."[233]

In founding the observatory the king had two objectives:

"To establish an observatory upon a liberal scale worthy the wealth and importance of the Government as well for the advancement of the noble sincerely new discoveries as for the defusion of its principles amongst the inhabitants of India, for the establishment is intended to embrace translation[234] into the native language and to instruct the inhabitants here. It is contemplated to deliver lectures upon astronomy to the students of the College and to select talented youth for instructions in every branch of the science....observatory instruments I believe to be commissioned from England. The officer to be placed in charge of the Observatory at Lucknow may correspond with the observatories of Europe and contribute to the advancement of astronomy by affording a consecutive series of important observations.[235]

We have given here a rather long quotation, so as to clarify the primary aim and attitude of the king. We shall refer to this point again in the last subsection.

The Governor General of India welcomed the king's suggestion very much and agreed to the appointment or transfer of Capt. Herbert, who on joining the king's service planned and supervised the construction of the observatory building and also ordered Troughton and Simms' astronomical instruments from England.[236] Unfortunately due to his sudden death[237] in 1833 the construction work at the observatory was held up till the appointment of Maj. Richard Wilcox (1802-1848) in 1835.[238] The following accounts, especially that of the astronomical work done in the observatory is based on the *unpublished* reports of Wilcox which he submitted to the then Governor General of India through the Resident of Lucknow, during the period 1840-1848.[239] They are as follows, their exact reference is given in the Bibliography:

I. Oct. 2 (1840),	II. April 1 (1841)
III. Oct. 1 (1841),	VI. Jan 18 (1844)
V. Feb, 25 (1845),	VI. July 9 (1845)
VII. Mar. 24 (1848).	

In the following we shall refer to these Reports by their Roman numbers only. We may mention that the gap between 1841 and 1844 was due to the return of Maj. Wilcox to his corps for active military service.[240]

Equipment

According to the report of the *RAS*, Lucknow Observatory was "certainly the best-equipped observatory in India".[241] In fact, its equipment consisted of the following instruments:

(i) A mural circle of 6 feet on which later a collimating eye piece invented by T. C. Taylor (of Madras Observatory) was mounted.[242]

(ii) An 8 ft transit.

(iii) An equatorial of more than 5″ aperture with the focal length of the telescope equal to 9 ft and the diameter of the hour circle of 2 feet.[243]
(iv) Astronomical clocks by Molyneux.

As to the quality of these instruments Wilcox remarked: "The Meridian instruments are upon the same scale as those at Greenwich, on the model of which they were indeed constructed by the same makers.[244] The Surveyor General of India even went a step further in praising the instruments. He wrote in 1852:"....I consider Lucknow instruments valuable and perfectly sufficient for a first class observatory. In fact they are *far superior to the apparatus in the Madras and Bombay Observatories*". [245] two claimants for these instruments appeared on the scene: Andrew Waugh, who wished to have an observatory at Calcutta "staffed and equipped from Lucknow, provided the instruments could be obtained free of charge"[247] and Capt. W. S. Jacob, who after reading the report of the *RAS*,[248] expressed his wish to obtain those instruments for the Bombay observatory.[249]

Astronomical Work

The programme of work which Wilcox chalked out for the observatory was conceived by him presumably in consultation with various astronomers, since then and later on he was in active professional correspondence with his contemporaries.[250] Extracts from his letters written to a member of *RAS* dated Jan. 7, 1846 and Jan. 22, 1847 were published in the above-mentioned report of *RAS*. In one of these Wilcox referred to an exchange of a letter with George Airy, This correspondence is extant in Airy's paper at the archives of Herstmonceux. In his letter dated Nov. 18 (1840), Wilcox asked Sir George, for instance, about

> "......the manner with reference to what is being done elsewhere these instruments may best be employed for the interests of science and as there is no one so capable as yourself of answering this question I venture to put it to you in hopes that you will favour me with your advice...."

In his reply Airy suggested to Wilcox to take advantage of his southern latitude in order to observe the planets during day-time and particularly to watch the smaller planets which should be better visible at Lucknow than in Europe, due to the clearness of the Indian sky.[251]

The following astronomical observations were performed at Lucknow by Wilcox and his Indian assistants:

1. Major planets during 5 a.m. to 11 a.m.;[252]
2. Smaller planets: *Ceres* and *Vesta* and occasionally *Pallas* and *Juno*[253]
3. Eclipses of Jupiter's satellites;[254]
4. Occultations of stars by the Moon;
5. Meridional observations of the "stars of the nautical almanac,......and a large number of small stars taken from the catalogues of the Astronomical Society and from those of Piazzi and Bode"[255] and also "reobservations.. of the stars of the third and fourth volume of Mr. Taylor's Madras Observations."[256]

Unfortunately none of Wilcox's observations (completely reduced for the years 1841-43) was ever published, however hard he tried. He corresponded with the secretary of the *RAS*[257] about this problem of publications, discussed it several times at length in his reports and even succeeded in securing Rs. 6000/- for publications from the king.[258] but in vain. Even after his death and the abolition of the observatory his wish to get at least the reduced observations printed could not materialize, although influential people like Dr. A. Springer, principal of Delhi College, Delhi made efforts to get it done.[259]

We would like to add here a few words about the team of Major Wilcox. It comprised two Indian assistants: Kalee Charan and Ganga Pershad, headed by a Greek called Kallanus, who formerly served in the great Trigonometrical Survey of India Wilcox expressed himself "....highly satisfied with the zeal and ability of my native assistants."[260] "....One could not wish for better observers than our educated lads turn out...."[261] Besides these technical hands there was also the afore-mentioned historian Kamāluddīn Ḥaydar who translated scientific works into Urdu, for instance Rev. Samuel Vince's *The Elements of Astronomy,*[262] or Lord Brougham's *Preface to Natura-Philosophy,* of the Library of Useful Knowledge,[263] or Astronomy by Brinkley.[264]

Abolition of the Observatory

On Oct. 28, Wilcox died.[265] The King of Oudh, Wajid Ali Shah (reigned 1847-56) ordered the abolition of the Observatory on Jan. 20, 1849.[266] The King justified it by claiming that "the great outlay incurred in maintaining it has produced no advantage whatever either to the state or to the people and learned of Oudh.[267] This reasoning is corroborated by Ḥaydar in his History, who further adds that according to a report to the King "the Europeans and not Indians are benefitted by this observatory."[268] However we may mention here another viewpoint also. The Resident at Lucknow, Lt. Col. W. A. Sleeman, claimed that the real reason for the abolition was the annoyance of the King at many remarks made by Ḥaydar in his History of Oudh.[269]

On the request of Col. A. Waugh, Cap. Strange visited Lucknow in 1855 for inspecting the instruments and records.[270] According to him the instruments were preserved well but required cleaning. In fact they were in such a good condition that within a few months a good astronomer could bring them in operation, added Cap. Strange. He therefore strongly pleaded for the resumption of work at the observatory by appointing an astronomer. He also found the records of observations *reduced* and *excellent.*[271] Again, he wished for the rescue of the observation records from the attack of white ants. The apathy of the Governor General is clearly demonstrated by their indecision to support the astronomical work at the observatory.

The result was its expected destruction in the Indian War of Independence in 1857 as reported by James Tennant.[272] Further, Markham noted that "all the work of this once first class observatory has been lost to the World, and its records have perished without rendering any result to science.[273]

Despite the above reports, we tried to search the original records of the observatory at Royal Astronomical Society and Royal Society of London. We could however, find in 1977 only at the Library of the Royal Society daily magnetic and meteorological observation of the years 1942-43 of the Lucknow (Magnetic) observatory.[274] Note, that Cap. Strange actually saw the "unsigned duplicate sheet" at the observatory in 1855, [275], Ḥaydar in his *History* writes, that at the time of abolition "a large number of school books were auctioned for Rs. 1300 and many of them were acquired by Dr. Sprenger and Wilson."[276] Since the former knew very well the value of Wilcox's observational work, and the latter was a trustee of King's grant of Rs. 6000 to Wilcox, for the printing of the observations,[277] it is most unlikely that the register of observations were not secured by them. We conjecture that those observations of 1841-1843 might be extant either in Sprenger's papers or with Wilcox' family.[278] Optimistically, we are stil in search of those observations,

Travancore Observatory

In 1836, on the suggestion of the Resident Gen. Stuart Fraser, an observatory was establish at Trivandrum by the Raja of Travancore, Rama Vurmah,[279] who was famoused for his love of learning and desired "that his country should partake with European nations in scientific investigation".[280] The building of this observatory was planned aud erected by Capt. Horsley (Madras Engineers) and was completed in 1837. Raja Vurmar appointed the astronomer and meteorologist John Caldecott (1800-1849) as derector of his observatory. Actually Caldeeott, who was working before this appointment as commercial agent to the Travancore Government at the port of Alepy, had been the first who "..pointed out to General Fraser..the advantages to science to be derived from the establishment of an observatory at Trivandrum".[281]

Caldeoutt started making observations in July 1837, to start with using his own instruments. However, in the following years on the advice of Raja Vurmah he went to Europe for the purchase of a "permanent instrumental outfit".[282] As a result of Caldecott's efforts the observatory was equipped with the mural circles by Simms and Jones respectively, a transit and $7\frac{1}{2}$ feet equatorial by Dolland, an altitude and azimuth instrument and a few astronomical clocks.[283]

With the aid of an Indian assistant, who was trained under T. G. Taylor at the Madras observatory, Caldecutt collected an enormous amount of astronomical observations which were forwarded by him to the Court of Directors of the East India Company and the Royal Society. His observations comprised also the computed elements for the comets of 1843 and 1845,[284] the solar eclipse of Dec. 21, 1843 which he observed near the source of the Mahe river where ,'it just fell short of totality but offered a beautiful view of Baily's beads".[285] All these astronomical and also other physical observations[286] brought him recognition. Already in 1840 he was elected a fellow of the *RAS* and also of the Royal Society. Unfortunately inspite of his utmost efforts he did not succeed in gatting his observations published. To that end he even made a journey to England in 1846, but in vain.

When Caldecott died in 1849, the observatory was for a short time under the supervision of Rev. Sperschneider, till John Allan Broun joined as its director in 1852. Broun was primarily interested in meteorology and particularly in terrestrial magnetism.[287] Therefore he later on devoted himself solely to magnetic observation for which he set up a special observatory at Agustia-Malley within three years of his joining the Trivandrum observatory. His extensive meteorological and magnetic researches were later published by him.[288] After Broun's departure in 1865 the then Raja of Travancore decided to abolish the observatory.

Poona Observatory

At Poona a small private observatory was established in May 1842 by Capt. W. S. Jacob (1813-1862). The octagonal shaped building of the observatory was done in brick and had a folding roof instead of a dome.[289] Jacob equipped this observatory with a 5 feet equatorial of Dollond.

During 1845-1848, working at his observatory he observed, for instance, the eclipses of Jupiter's satellites, in order to determine particularly the longitude of Poona, and he also carried out observations of Saturn's rings. All those observations he communicated to *RAS*.[290] Jacob's main interest, however, lay in the observation of double stars of which he also compiled a catalogue. Actually he became famous for that catalogue of 244 binaries, also for the calculation of the orbits of a number of binaries and particularly for the triplicity of Scorpii in 1847.[291] His work was recognized by his eldction to the Fellowship of *RAS*.

In 1848 Jacob was appointed director of the Madras observatory in which capacity he worked for 11 years.[292] Since the climate of Madras did not suit him, he cherished the desire to have a bigger observatory set up at Poona or Bombay. Already in 1852 he wrote in a letter to *RAS* that the climate of Poona is the best, "where the air is cooler and the climate less adverse to exertion", and that even the climate of Bombay is "superior to that of Madras". He therefore proposed that "no doubt it would be an advantage to science if that (i.e. then Bombay observatory) were made the principal observatory.[293] To that end he also suggested that the instruments of Lucknow Observatory (after its abolition) be transferred to Bombay. On resigning from the Madras observatory because of ill-health he must have actively worked for the realization of his afore-mentioned wish and in fact succeeded in obtaining in 1862 a grant of the British Parliament worth £1000 to build an observatory at Poona at a height of 5000 feet. On returning to India he purchased a 9 inch equatorial from Lerebours for his observation but 8 days after arriving at Bombay he died in Poona on Aug. 16, 1862. Thus his desire "that an astronomical observatory should be established in the Western Presidency....(was) never fulfilled."[294] Jacob's private observatory completely lost its stimulus after his death. Actually so far as the promotion of astronomy in Inida is concerned this observatory did not play any significant role.

Takhta Singh Ji Observatory

The spirit behind the establishment of an astrophysical observatory at Poona was actually a Parsi physicist Kavasji Dadabhai Naegamvala (1857-1938). Naegamvala belonged to an illustrious family of Parsi contractors,[295] He was educated at the Elphinston College (Bombay), from where he passed his B.A. (1876) and M.A. (1878) in physics and chemistry winning the Chancellor's gold medal for the year 1878. In the same year he was nominated a senior Dakshina fellow of the College. He secured the first lectureship in experimental physics instituted in 1882. From 1881 to 1912 he was a nominated Fellow of the University of Bombay. In 1888, he was transferred to Poona to the College of Science (now College of Engineering) as a professor of astrophysics[296] and in 1900 he was nominated as Director of *Maharaja*

Takhtasinghji Observatory, Poona. Naegamvala's astrophysical work[297] was recognized internationally by his election as the Fellow of Royal Astronomical Society.[298]

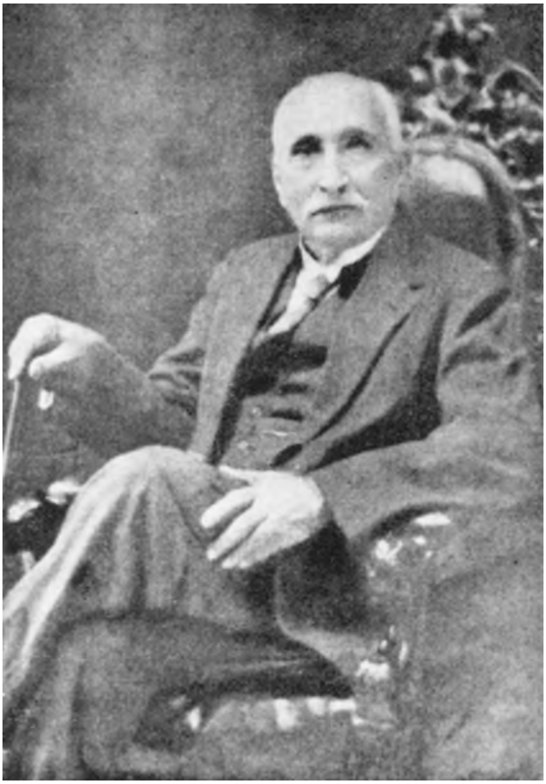

Fig. 12.2 K. D. Naegamvala

The Establishment

In October 1882 Maharaja Takhta Singhji of Bhavanagar visited the Bombay University. Naegamvala represented to the Raja "that adequate means for the pursuit of spectroscopic investigation did not exist in any of (the) Colleges affiliated to the Bombay University and that Elphinston College would be prepared to organise a spectroscopic laboratory, if provided with a sum sufficient for the purpose."[299] The Raja offered a sum of Rs. 5000 and also hoped for a matching grant by the Government to establish such a laboratory. His motivation was two-fold:[300]. . . .on one hand I shall have the satisfaction of knowing that I had done something to supply a very desirable means for study of an important branch of science. I shall on the other hand, have the gratification of thinking that it has permitted me to perpetuate the momory of my present visit. . . . . .". By a strange coincidence, a spectroscopic observatory instead of a laboratory was established.

Soon after the discovery of solar spectral lines by Fraunhoffer (ca 1812-1814), their explanation by Kirchhoff and Bunsen (about 1859) the spectroscopic technique was applied to the stars and planets by W. Huggins (in England), H. C. Vogel (in Germany) and Father A. Secchi (Rome)..[301] The latter had contacts with Father Lafont, who was the director of St. Xavier's College Observatory at Calcutta (established about 1875).[302] Only spectroscopic laboratory in India was then at Calcutta where Fa. Lafont was engaged in studies in solar[303] and stellar spectra evidently with the aid of a telescope. It was therefore natural for Naegamvala to visit that laboratory at Calcutta, in order ɔo familiarize himself with the spectroscopic apparatus. Celestial spectroscopy was then the frontline experimental physics, also called Astronomical Physics.[304] Evidently Naegamvala became interested in a spectroscopic observatory. He then communicated his ideas to Principal Wordsworth and got dimself recommended for visiting various laboratories and observatories in Europe by Father Lafont and Father Deckmann (Prof. of Physics at St. Xavier's College).[306]

In 1884, Naegamvala proceeded to Europe "on leave without pay" and a grant of Rs. 10,000 to select apparatus in consultation with the Committee on Solar Physis and the Astronomer Royal).[306] However he first visited several astronomical observatories, "at College Romano at Rome, Astrophysical Observatory at Potsdam, New Observatory of Astronomical Physics..in the domain of Meudon near Paris" and surely Lockyer's Solar Physics Observatory at South Kensington, where particularly he took a training in handling the relevant apparatus.[307] Naegamvala compiled a list of equipment, and got it approved by Astronomer Royal Sir W.H.M. Christie, and returned to India. His ideas to establish "an astrophysical observatory in India at future date" crystalized further by visiting the above-mentioned European Observatories. To start with, he attempted to shift the site of the observatory from Bombay to Poona at the College of Science (presently College of Engineering). He held simultaneously the posts of the curator of the observatory and lecturer in astronomy and optics at the College of Science, Poona.[308]

The Equipment and Astronomical Work

By the end of 1888 the Observatory was ready and Neagamvala announced its establishment by writing to *RAS*.[309] According to him the principal instruments were then: 16 ½ inches silver-on-glass Newtonian by Sir H. Grubb, with a 4" finder attached, an equatorial reflector by Cooke, and several spectroscopes by Grubb, Hilger, Browning.[310] In the following years the equipment was added and continuously improved: The 16½ reflector "was adapted both for visual and photographic work and supplied with electric control, a 12″ siderostate by Cooke and an 8″ lens by Grubb for solar spectroscopic work, also a 3″ transit and a Morse-type chronograph, a sidereal clock, by Cooke.[311]

It should be noted that this equipment was the most modern one at that time in India. Even the Madras Observatory did not possess such instruments for astrophysical work; Michie Smith was then only making efforts to establish a solar or astrophysical observatory at Kodaikanal.[312] Naegamvala was doubtless well aware of the excellent quality of his equipment. He wrote to Sir Christie:

> "My earnest desire is that this splendid equipment that I have managed to bring together should not lie idle and that I may be put in a position to make use of it."[313]

In reply Christie suggested :

> "It is very desirable that the fine equipment of the observatory..should be fully utilised as such valuable work might be done with it at a station like Poona near Equator where observations of the Sun, Moon, Planets etc. could be made under much more favourable conditions than in our Northern Observatories. India seems to be peculiarly marked out for observations of the Sun, especially spectroscopic,..".[314]

Following the suggestion of Christie, Naegamvala turned out best work on the observation of the solar chromosphere and corona, at the time of total solar eclipse on Jan. 22, 1898 for which he led an expedition to Jeur (Western India).[315] According to the late M. K. Vainu Bappu (Director, Indian Institute of Astrophysics, Bangalore), Naegamvala's solar work "is the first complete Indian efforts of its kind on record."[316] Fortunately a report of that meticulously planned expedition was printed and is still available.[317] Besides, he communicated also his *Solar flash spectrum* to the *Astrophysical Journal.* The Editor's remarks are noteworthy: "Perhaps the most interesting feature of the photograph is the prominence shown in two lines *H* and *H*-delta, but invisible in *H* & *K* and the hydrogen lines.[318]

Besides the above-mentioned work, Naegamvala indulged also in astrophysical observations. He carried out spectroscopy of Orion Nebula, Nebula H I, 43 Virgini great sunspot group of Feb. 1892, and also observed the transit of Mercury on May 1891, Nova in Perseus on Feb. 25, 1901, and Nebula NGC 6595.[319]

Ironically in the same year 1898, when Naegamvala did his most important work he was critized in India for "failing to produce any worthwhile astronomical research"[320] On the ground that he was simultaneously holding a teaching position at the University of Bombay.[312] As a matter of fact Naegamvala himself was conscious of this problem. Already in 1896 he wrote to Christie:[322]

> "As long as I am required to teach Physics....it would be idle to expect me to have either the energy or time to accomplish anything."

All the same he did stick to his position at Bombay University during his directorship of the Observatory which can be amply understood by the following remarks of Luckyer in his *Report on Indian Observatories* (1898):[323]

> "The chief disadvantages under which scientific men now labour in India are want of promotion and of graded increases of salary throughout their service. Men of Science are after all men, and are no more likely than others to work heartily without any hope of increased pay or advancement, especially when they are reminded by the promotion and increased emoluments granted to those in other branches of the same state service of their own waterlogged condition."

Inspite of his best efforts Naegamvala could not secure a graded post even up to 1899 though the Govt. of India recognised already in 1887 Naegamvala "as practically qualified for a graded appointment".[324]

Along with his two-fold engagement, however, Naegamvala directed the programme of the observatory excellently. Vainu Bappu remarks about his solar eclipse observation:

> "The report of this successful expedition indicates the *great care and thoroughness* that went into the planning of the expedition".[325]

With his work on the solar corona Naegamvala corroborated Lockyer's opinion about him "as the only person in India at that time who was well qualified to carry out worth which investigation into solar physics."[326]
As a matter of fact Naegamvala's astrophysical work was also praised by Huggins (England), Vogel (Germany), Hale (USA) and by Maunder, Vice-President of *RAS*. Further his work was cited in Clerk's *History of Astronomy in Nineteenth Century*, and in the *Progress of Astronomical Photography* for 1895 and 1897.[327] According to one remark, Naegamvala carned a name in three continents",[328] and it was also conjectured that Sir Norman was "of opinion that the claims of Mr. Naegamvala to be the director of the Imperial Observatory of Astrophysics should not be neglected".[329] Notwithstanding all the afore-mentioned admiration of Naegamvala's scientific work and of his talents, it was decided by the Govt. of India to abolish the observatory after retirement of Naegamvala in 1912. The order was carried out, the observatory was dismantled and the instruments were transferred to Kodaikanal Observatory. For lack of time and space we can not go into the background intrigues of the abolishment of that excellent observatory, in which the then Director-General of Observatories, especially the Meteorological Reporter, J. Elliot, and also the Director of Astrophysical Observatory at Kodaikanal were involved.[330]

Miscellaneous Observatories

Observatories at St. Xavier's and Presidency Colleges:

The St. Xavier's College Observatory (Calcutta) was established in 1875 and initially Father Lafont was the astronomer-incharge. As mentioned before, Father Lafont was in close touch with Father Secchi of College Romano and consequently he could establish at the St. Xavier's College (Calcutta) a good spectroscopic laboratory in order to carry out solar and stellar spectroscopic work. As Naegamvala [331] noted, there existend then in India only one spectroscopic Observatory, the work of which consisted of "the delination of the forms of the solar prominences and spots with the object of supplementing. .similar observations. . (at). . the College Romano." Fa. Peneranda, the Director of the Observatory in about 1891 observed also other phenomena, e.g. the transit of Mercury,[332] observation of several solar eclipses.[333] However later Fa. Francotte shifted to meteorological work, a fifty years report of which from 1868-1918 was also compiled by him.[334]

So far as the equipment of the observatory is concerned it may be mentioned it had then valuable instruments, namely "two 9″ refractor and reflector equitorials also equatorials of 3" and 4", four transits and spectroscopic equipment."[335] The observatory is presently meant only for teaching.

The observatory at the Presidency College was constructed in 1900. It funded by Maharaja of *Tipperah,* who presented 4.5″ Grubb's reflector. Later in 1922 8″ telescope was added. It was a gift from the Astronomical Society of India.[336]

Observatories at Dehra Dun

Built in 1884, the Hennessy Observatory was meant as the large photoheliograph observatory for obtaining 12″ photos of the Sun. It was named after J. B. N. Hennessy who started his survey work in 1844 and by 1883 he became the Deputy

Surveyor General of the Trigonometrical Branch. In 1884 he retired; he was a Fellow of the Royal Society.

The photoheliograph mentioned above was not in operation when Lockyer visited the observatory in 1898. But he found another one in operation, namely Dallmeyer 8″ photoheliograph.[337] Lockyer noted the importance of the observatory (and also one at the Mauritus) for filling the gaps in rhe Greenwhich series.[338] He pronounced his opposition to the shif ing of .he observa ory at Kodaikanal, as suggested by Elliot, the Meteorological Reporter.

Another observatory built in Dehra Dun in 1886 was named after Maj. General C. Haig (Deputy Surveyor General of the Trigonometrical Branch). To start with, the observatory was meant as a depository of large astronomical instruments for latitude observations. They comprised Ramsden's zenith sector, Strange zenith sector, two astronomical circles and a zenith telescope; all made by Troughton and Simm. (London) It may be noted that the meridian of Dehra Dun longitude station passes through the observatory. Both these observatories are no longer in working condition.

THE CONTROL BY ASTRONOMERS ROYAL

The Royal Society

From its inception in 1660-63, The Royal Society at London (hereafter abbreviated as *RS*) was also the chief authoritative advisory body for the British Government in scientific matters of both national and international importance, though actually it was founded for "improving the natural knowledge by experiments". The British Government sought its advice on calendar (in 1751), geodetic and trigonometrical surveys (1784, 1791) and, as mentioned before, in the supervision of expedition for the observations of Venus transits in 1761 and 1769. Fellows of *RS* were also members of the visiting committee for the improvement of Royal Greenwich Observatory (hereinafter as RGO). The *RS* responded to each government request by forming a relevant committee, e.g. a joint permanent solar eclipse committee in which *RAS* and *RS* were involved.[339] Evidently the same procedure was followed for scientific development in India.[340]

The Indian Observatory Committee (IOC) was constituted in 1885 by the President to monitor the efficiency of the Madras and Bombay Observatoriel. This Committee[341] comprised fellows of the *RS* and of the Royal Astronomical Society, and of course, as most important member, the Astronomer Royal himself. In 1897 IOC was merged with a more general (imperial) Observatories Committees (OC), the terms of reference of which were not confined to Indian affairs alone.[342] In 1898 Astronomer Royal W. H. M. Christi was appointed the Vice-chairman of OC.

The IOC and OC played quite an important role in the development of astronomy in India.[343] However, since the most influential and competent member of these committees was the Astronomer Royal, we deal in the following only with his direct influence and control of the development of astronomy in India.

Nevil Maskelyne (1732-1811)

The first contact of an Astronomer Royal with India dates back to Rev. Nevil Maskelyne's directorship of RGO during 1765-1811. His connections with the early surveyors in India definitely promoted Indian geographical surveying,[344] in the development of which the origin of observational astronomy in India is to be sought. Among those surveyors, to name a few, were the mathematician and astronomer Reuben Burrow (1747-1792)[345] who is known to have been earlier an assistant of Maskelyne, and James Rennel (1742-1830), the "father of (modern) Indian geography", to whom Maskelyne explained the nature of the Indian survey.[346] Later on also Maskelyne kept himself acquainted with the progress of the geographical survey; it was through him presumably that Major William Lambton (1753/6-1820) secured the latest literature on geodesy for his work in India. Perhaps even more important than the professional advice was the encouragement Maskelyne gave to Lambton; Sir C. Everest (1790-1866), Lambton's one-time assistant, related:[347]

> "To this moment I remember well the gleam of gladness with which my old master used to refer to the fact of Nevil Maskelyne's letter. It had reached him apparently in an appropriate hour when he was surrounded with difficulties.. with this solitary exception, until Professor Playfair took the subject up....[348] he was to appearance forsaken of all, and left to struggle alone..whilst his labours were treated by all his countrymen..with the utmost superlative indifference and neglect."[349]

We may recall that it was still during Maskelyne's time that on the initivative of another surveyor, Michael Topping, the first observatory for modern astronomy was established at Madras.

Sir G. B. Airy (1801-1892)

The Astronomer Royal (AR), Nevil Maskelyne was succeeded by John Pond (1767-1837) AR during (1811-1835)—on whose recommendation T. G. Taylor secured the directorship of Madras Observatory.[350] However, presently we do not know whether Taylor had an active correspondence with Pond or Sir Airy, who was in turn the successor of the former, AR during 1835-1881,[351] On the other hand, the excellently preserved papers of Airy at Hersmonceux contain his extensive correspondence with various astronomers in India, for instance, Wilcox, Tennent and quite substantially with Pogson.[352] As mentioned before, AR was one of the most important members of the Indian Observatories Committees and was supposed by E.I. Co. to supervise its observatories in India. All the same Airy's keen interest in or control of the astronomy programme in India is illustrated by a few selected examples in the following.

Let us recall the correspondence between Major R. Wilcox and Sir Airy[354] As a reply to Wilcox's consultation, Airy advised him "as a general rule (to observe) those objects which you find yourself able to measure most easily and most accurately are best worth following.." However he also gave him a definite advice for observations, namely:

(1) "The planets not at opposition but at the earliest and latest seasons when they are observable in the morning....in the evening;"

(2) "The minor planets....eclipses of Jupiter's satellites and occultations of stars by the moon";

(3) "The southern double stars,"

(4) "and all the small stars which are near to or included in Herschel's. Besides he quite modestly added that it was not for him quite easy to chalk out a course for some one else and that his suggestions might be contrary to Wilcox's under standing of the situation.[354]

In later years, however, his ideas developed on different lines, when Lord Cranbor from Indian Office (London) called on him in 1866 and discussed with him the maintenance of Bombay and Madras Observatories.[355] After getting prepared a memorandum on the aims and objectives of an observatory,[356] Airy observed, "that it is owing to the steadiness of plan produced by the definitions of duty contained in the Royal Warrant and Admiralty instructions to the Greenwich Observatory, that the Observatory has been the most useful in the world." And naturally he suggested "a similar document together with provision for the periodical reports," for Madras Observatory.[357]

In that *Code of Instructions* which consisted of nine sections particular stress was laid on the meridian observations, in order to supplement those of Greenwich, Cape of Good Hope and Australian Observatories. Also the Madras astronomers, although allowed to do "special investigations" (i.e. of their own choice), were especially asked"....not to interfere with the regular routine of the observations". Probably in order to ensure the latter it was further asked that "monthly tabular statements of arrears of reduction and publication (i.e. annual volumes and reports) should also be submitted" to the Astronomer Royal.[358] Quite a rigid control no doubt! However POG the Government astronomer at Madras rightly objected to that type of control. He suggested that since.[369]

> "Public opinion would be no check in this country....what then is required is that an annual statement should be drawn up by the Madras Astronomer, to be submitted to Home Government, through Astronomer Royal......An arrangement of this character, while securing the application of a check upon the Madras Observer, would not subject him to a direct pressure from the Astronomer Royal; and I must remark that to place the Astronomer here under direct orders......would cramp the energies of the former, and take away from him that independence of feeling which is essential to a successful follower of Science".

A very sound advice indeed by a real scientist!

SIR W.H.M. CHRISTIE

The successor of Airy, Sir W.H.M. Christie, appears to have been unaware of the Code initiated by Sir Airy, According to a remark of Sir Lockyer "The Indian Government believed the Astronomer Royal in England was in overall control of the Indian Observations whereas the Astronomer Royal was equally clear that he had no such responsibility"[360] However, Christie did continue some sort of contacts with the astronomers in India; we have already dealt with his communication (advice) to Naegamvala.[361] He even came to India himself in 1898, heading a solar eclipse expedition, and utilized this opportunity to tour a few Indian observatories, viz. those at Bombay, Madras and Kodaikanal; the establishment of the latter he had effected through the Indian Observatory Committee. On that tour the Meteorlogical Reporter (also Deputy Director of the Madras Observatory) Mr. J. Eliot looked after him.[362] After his return Christic wrote a *Report on Indian Observatories*,[363] in which he suggested in particular some modifications to Eliot's proposals[364] for the improvement of the work of astronomical and magnetic observatories in India, though agreeing to its acceptance "as a sound basis for the reorganization of Indian Observatories."[36] We shall not go into other details of that important report here but shall confine ourselves to one point only, namely the control, which according to him should comprise:[366] an annual inspection "by a Board of Visitors, composed of Surveyor General, the Meteorological Reporter, a couple of Indian Government officials; and also an annual report to be submitted to committee in England. Bui Christie was very clear about the independence of astronomers working in India. He further added that "nothing should be done to weaken the sense of responsibility of the Government Astronomer and that he should not be placed under the direction of any other official. He alone should be responsible for making the observations considered advisable and for their discussion and publication."

Sir Norman Lockyer

A more comprehensive report on Indian observatories was however compiled by Lockyer who was not an Astronomer Royal.[367] That report was in response to a request by Indian Office (London) to inspect the Indian observatories on his return from 1898 solar eclipse expedition headed by Lcokyer himself.[368] Lockyer visited all meteorological observatories (Calcutta, Bombay and Madras), magnetic observatory at Bombay, astronomical observatories for time at Calcutta and Bombay, general astronomy at Madras and for solar physics at Dehra Dun and Poona (the director of the latter was Naegamvala). He describes in his report the instrumentation and work of each observatory, gives his own critical remarks about Government scheme, and administration of the observatories, and argues extensively for the establishment of an Indian Solar Physics Observatory at Kodaikanal. Further, he depreciated the non-astronomical routine work at these observatories, expressed his impression of a lack of coordination and control, also of rationalization of work done there. He recommended strongly for the astronomers working at those observatories *more* time to do pure research.[369]

In short, that report along with the one by Christie exercised a very important influence on the further development of modern astronomy in India. In fact, we in India owe much to Lockyer for the development of Kodaikanal Observatory as a Solar Physics Observatory, and which paved its way to become an astrophysical observatory later.[370]

THE CONDITIONS OF SCIENTIFIC WORK

Without going into the details of colonial science policy of the then Government in 19th century India on which some work has recently been done,[371] we outline in the following first the socio-economic conditions in which even the astronomers of European descent worked in 19th century. According to our investigation,[372] the main problems of the astronomers then were,

(i) the emoluments of the astronomers in contrast to administrators;

(ii) the possibility of promotions and a graded service,
(iii) the attitude of the colonial administration towards the scientists and scientific work, *per se*.

The records show that the second government astronomer at the Madras Observatory, John Goldingham, drdwing a salary of 192 Pagoda (1 Pagoda, a gold coin=3—4 Sonat Rupee), concurrently worked for a few years as an architect or civil engineer also, i.e. as incharge of all buildings at Madras town. He was allowed to earn a commission of 15 p.c. on the total cost for building and repair in order to supplement his earning. We have already mentioned another example of K. D. Naegamvala, Director of the Takhta Singhji Observatory at Poona, who was simultaneously working as a Professor of Physies at Bombay University.[373] Evidently such a double employment was due to a low salary structure as corroborated by the following evidence.[374] According to N. R. Pogson—Director of Madras Observatory 1861-1891—the director's salary was raised some time in the eighties of the last century from Rs. 672 to Rs. 800. Yet it was quite inadequate and "not befitting his rank in science". For comparison a principal of a high school then got a salary of Rs. 1000, first class officers of the Trigonometrical Survey of India drew not less than the same amount, while the starting pay of the Meterologist to the Government of India was Rs. 1350. Besides, Pogson's assistants—first his son and later his daughter-were just drawing Rs. 150, "equal, I (Pogson) suppose, to that enjoyed by Governor's coachman or cook, a fifth of that a native or East India Deputy Collector.[375] No wonder Pogson had to earn an extra Rs. 250 p.m. by supervising meteorological observations, which he could ill afford to forego in view of his large family of eleven childrep.[376] Many a time in his letters to Astronomer Royal Sir Geoge Airy, Pogson complained about his low economic position and inferior status to other officers of the Government of India.

A similar opinion was voiced by Sir Norman Lockyer in his Report as quoted before.[377] The policy "of treating its (Govt. of India) scientific savants on a different principle from that adopted in other department", was surely unconducive to the promotion of science. Besides, Lockyer also noted the contempt with which the scientists were regarded by the British Administrators. In fact according to J. F. Tennant, Director of Madras Observatory (1859-1860).[378]

> "..in high Indian circles men of Science are considered as loafing imposters who trade on the general ignorance at home".

Naturally, Sir Lockyer pleaded for a better status for scientists in India and for the recognition of their work.

So far as the technical difficulties under which scientific work was carried out at these observatories are concerned, we may add the following. Too much routine work like overhauling of ship's chronometers, meteorological and magnetic observations swallowing away the precious time of a good astronomer were probably the main handicraft. It was true for Madras as well as for Lucknow. So much so that the Governor General even ordered an explanation from Col. Wilcox why a meteorological and magnetic register was not kept at Lucknow observatory.[379] Wilcox pleaded "not guilty of any lapse, since he was not aware that meteorological registers were supposed to be a part of his duties. He further argued:" I have not found any instance of their being indebted to any observatory for their meteorological journal......In short, meteorology is considered quite separate from the science of astronomy.[380] Despite that explanation Wilcox did keep meteorological and magnetic registers and carried out those observations regularly.[381]

It was the same case with Pogson at Madras. He had to do also meteorology for financial reasons, although he was of the opinion that "to require such an officer (an astronomer) to neglect his far higher pursuits and dabble in such comparative trifling as Meteorology is past all endurance". He equated the indulgence of an astronomer in meteorology "as a fall" and lamented at his soiled reputation for the sake of earning a few more Rupees by meteorology.[382] He recommended very strongly that "the astronomer.... wherever he may be located should be left alone.... Separation from the Meteorological Department of India and perfect freedom from every thing which can interfere with his astronomical duties should be enforced." He bitterly suggested as an alternative that "the observatory should be at once and for ever swept away as a luxury no longer needed."[383]

As a tail-piece it may be added that the recommended separation could be brought about only in Independent India with the untiring efforts of the late M.K.V. Bappu in the seventies, when he succeeded in founding the Indian Institute of Astrophysics, situated now at Bangalore.

CONCLUSION

It is clear from the preceding section that the promotion of the science of astronomy (in fact for that matter any basic science) was not the aim of the British Colonial Government in India, although the Indian mind was quite receptive and anxious to learn the new sciences. We have already cited the example of Raja Jai Singh's use of telescope and his association of Jesuits with the astronomical programme at his observatories. Another example in support of this receptivity is the commissioning by Dānishmand Khān (Mughal Governor of Delhi) of the Persian translation of the works of Descartes and Gassendi, as reported by Jesuit traveller Bernier, who visited India from 1659 to 1667.[384] As a consequence, a channel of communication between India and Europe was developing fairly well in 17-18th century. However with the commencement of the colonization of India by the Europeans: Portuguese, French and English, in the 17th and its intensification in the following century, that intellectual communication between India and Jesuit scholars broke down gradually.[385] The reasons could be: the weakening of the Mughal Central Authority, the rise of local rulers, the political manipulation and military successes of well-organized European colonialists especially British in the disguise of traders, and the resulting chaos in the then socio-economic system. The ensuing situation in turn cut off completely the patronisation of sciences and arts by Indian monarchs and local rulers. Last but not the least, the increasing proselytization activities of several christian missions under the patronage of respective European powers bred distrust among Indians about the selfish design of the Jesuits and other missionaries. It is no wonder tha all the socio-political circumstances arrested altogether even the reception of the secular knowledge from Europe and nipped the buds of the probable flowering of a scientific renaissance in 19th century India.

Modern Astronomy in Persian—the Indian Effort

We have mentioned the programme of translation of European physical sciences into Urdu, which was sponsored by King of Oudh, *Nasiruddin Ḥaydar,* in the first half of 19th century. But a number of works on modern European astronomy were written before and at about the same time, in Persia and/or Urdu. A selected list follows:

1. Muḥammad Ḥussayn ibn 'Abdul Azīm Al-Ḥusaynī Al-Isfahānī d. 1790, *Risāla der ahwāl mulk-i farang wa hindustān* (in Persian). The monograph is an account of author's journey to Europe during 1772-73, manuscript extant at Aligarh, Bombay and Hyderabad.

2. Abu Ṭālib Al-Ḥussaynī, *Risāla dar hay'at-i jadīd* (a monograph on modern astronomy in Persian), manuscript extant at Rampur, completed in 1798.

3. Abul Khayr ibn Mawlwī Ghiyāthuḍḍīn, *Majmū'a Shamsī* (a monograph on Corporation system), MS at Bombay, Delhi and Hyderabad. The Persian text was published at Calcutta in 1826, and its Urdu translation in 1843.

4. Anonymous, *Miftāh al-aflāk* (Key to Heavens). It was first published in Urdu at Calcutta in 1833 and later translated ino Persian for scholars in 1847 Wājid 'Al Shāh–King of Oudh's time.

5. Mawlwī Shamsuddīn, *Sitta-i Shamsīya,* a set of six monographs on various sciences, one of which is also astronomy. It is supposed to be Urdu translation from English and was published in 1836.

It is not the place to describe briefly the contents of the above selected monographs. It is enough to add that the above-mentioned works deal quite well the Copernicus' system, Newton's and Herschel's contributions to astronomy. They deal also especially with the telescope. In fact about the same time Herschel's *Principles of Astronomy* was also translated into Urdu. Unfortunately that wave of Persian works on and Urdu translations of European sciences died with the introduction of English language as medium of instruction in Indian schools and colleges. Note that translations into Latin of Arabic[386] and Greek works in Europe during 12-13th century were the pre-requisite for "the revolution in attitude and ideas" during renaissance which Bernal calls "as the first phase of scientific revolution".[387] Thus the imposition of English gave a death-blow to the possible scientific revolution even in its birth.

Summary

As shown in sec. 5, the science policy of the colonial Government in India was not at all conducive for the development of the science of astronomy, carried out even by Europeans at the Government observatories. By its very nature the EICo and later the then Government of India was interested only in the commercial exploitation of India and not in any kind of public services like education etc., apart from the "production" of English knowing clerical staff especially of lower ranks for its administrative machinery. In fact it was a patriotic band of Indians, for instance Raja Ram Mohan Roy (1772-1833) and Sayyīd Aḥmad Khān (1817-98), who relentlessly fought for the teaching of modern European knowledge particularly of sciences in the Indian schools and colleges, since they became quite conscious of the downfall of the indigenous system of education because of its lagging behind with the develop-

ment of knowledge in Europe and also for want of patronage by Mughal Kings, rajas and nawabs. Though the British rulers were thus compelled to introduce sciences like physics and chemistry in the English-medium schools and colleges, yet astronomy was not integrated into that system of education, despite its central role in the curricula of both Muslim (Persian-medium) and Hindu (Sanskrit-medium) indigenous educational instituties. Thus the few observatories established in the 19th century at Madras, Bombay and Calcutta remained in effect *alien outposts of a foreign science.* The directors were naturally all Europeans and almost all Indians employed there were kept as mechanical computers, or for menial work. Not a single government observatory was then attached to any educational institution, apart from the private Takhtasinghji Observatory at Poona College, which was also manoeuvered into abolition after the retirement of its director K. D. Naegamvala, the first astrophysicist of India.[388]

European astronomy in India, inspite of its institutionalization in the sense the establishment of a number of observatories, could not become an integral part of Indian educational system. This British legacy is being gradually eliminated, though with difficulties by those astronomers/astrophysicists who are working at the Indian universities presently. However, this remark does not imply that independent India is still lagging behind the modern developments in astronomical/astrophysical research. In fact India has produced in this century one of the few world-renowned astrophysicist namely, M. N. Saha. Besides, by commissioning two 40″ telescopes (of Carl Ziess Jena) at Nainital and Kavalur, constructing of a 90′ telescope indigenously at the Indian Institute of Astrophysics, Bangalore (first Director, late M.K.V. Bappu,) setting up of telescopes, for radio, millimeter and infra-red spectral regions at Ooty, Bangalore and Mt. Abu respectively, and by launching of the Indian Satellite Programme, modern astronomy in India has already come off age after indenpence.[389] With pride we note that these efforts have been recognised internationally, especially by the election of late M.K.V. Bappu as President of the International Astronomical Union (IAU) for 1979-82, and by the holding of XIX General Assembly of IAU in India this year in November.

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