ASTRONOMY IN INDIA DURING THE PERIOD 1787 - 1947.

Astronomy is one of the sciences which has had much stimulus to its advancement by virtue of the contributions made by early Indian thinking. The efforts of Aryabhatta, Varahamihira, Brahmagupta and Bhaskara are monumental and have been covered elsewhere in this volume. Little if any astronomical activity existed in India over the next five centuries until Jai Singh performed the incredible feat of building five observatories and making observations of accuracy with them in a little under four decades. These institutions contain enormous instruments of masonry, many of which were invented by Jai Singh, and were meant to mutually confirm and check the observations made. Magnificent in concept, they were seldom used after Jai Singh and with the new era of telescope technology already a hundred years old, they retreated rapidly into obsolescence. One can only wonder what a Jai Singh, better informed of contemporary happenings, would have left behind to posterity.

The Madras Observatory: The East India Company having resolved to establish an observatory at Madras for promoting the knowledge of Astronomy, Geography and Navigation in India, Sir Charles Oakeley, then President of the Council, had the building for the observatory completed by 1792. The Madras series of observations had commenced in 1787 through the efforts of a member of the Madras Government - William Petrie - Who had in his possession two three-inch achromatic telescopes, two astronomical clocks with compound pendulums and an excellent transit instrument.

This equipment formed the nucleus of instrumentation of the new observatory which soon embarked on a series of observations of the stars, the moon and eclipses of Jupiter's satellites with the accurate determination of longitude, as its first concern. The pier that carried the original small transit instrument in a massive granite pillar and has on it an inscription in Latin, Tamil, Telugu and Hindustani so that "Posterity may be informed a thousand years hence of the period when the mathematical sciences were first planted by British liberality in Asia". In any case this quotation from the first annual report of the observatory is atleast a record of the fact that astronomical activity at the Madras Observatory was indeed the first among British efforts at scientific studies in India.

The longitude of the Madras Observatory has a most important role as a fundamental meridian from which observations for longitude in the Indian Survey are reckoned. The accuracy with which a map of India fits into a map of the world depends solely on the accuracy of the longitude determination of the transit instrument pier at the Madras Observatory. The work of the Great Trigonometrical Survey of India commenced at Madras on April 10, 1802 when a baseline measurement related to the Madras longitude was made.

For over a century the Madras Observatory continued to be the only astronomical observatory in India engaged in systematic measures of star position and star brightness. Goldingham,

Taylor, Jacob and Pogson were the Government astronomers who dominated activity at Madras. With a new five feet transit, Taylor completed in 1844 his catalogue of places of over 11,000 stars. Double star catalogues, measures of their separation and the determination of their orbits were Jacob's principal interest. The observatory received a new meridian circle during his tenure and with it, besides observations for the determination of star position and evaluation of proper motions, a series of observations of the satellites of Jupiter and Saturn were commenced. From 1861 until his death in 1891, N.R. Pogson as Government astronomer, in keeping with progress in the science, entered into newer areas of observations. While the transit instrument and the meridian circle were both usefully utilized for a star catalogue of 3000 stars that included standard stars, large proper motion stars, variable stars and the like, it is with the new 8-inch Cooke equatorial that he made discoveries of asteroids and variable stars. The asteroids Asia, Sappho, Sylvia, Gamilla, Vera and the variable stars Y Virginis, U Scorpii, T Sagittari, Z Virginis, X Capricorni and R. Reticuli were all first discovered visually at Madras either with the transit instrument or by the equatorial instruments. The discovery in 1867 of the light variation of R. Reticuli by C. Raghunathachary is perhaps the first astronomical discovery by an Indian in recent history. Pogson also undertook the preparation of a catalogue and atlas, of variable stars complete with magnitude estimates made by him

of both the comparison and the variable. These were edited by Turner after Pogson's death.

During this period the Madras Observatory participated in observations of the important total solar eclipse that were visible from India during the nineteenth century. These were the eclipses that established the foundations of astrophysics and especially of solar physics and in these observations the Madras Observatory's contributions were most significant, as will be seen latter.

An Indian Observatories Committee in England advised the Secretary of State on matters pertaining to the administration of the Madras Observatory. In many respects, with no adequate staff to help him, Pogson had taken on more programmes of work than he could bring to a successful termination. There were questions raised in London in 1867 whether the Madras Observatory need be continued at all since the British had started some other observatories in their possessions in the Southern Hemisphere. It was even recommended that the Madras Observatory should concentrate more on publication of the observations already made, than make new ones. The work of Pogson was commended on, and questions on the closure of the Madras Observatory relegated to the time when Pogson would retire.

Meanwhile in May 1882, Pogson had proposed the need for a twenty inch telescope which could be located at a hill station in South India engaged in photography and spectrography of the sun

and the stars. The proposal received active support both in India and Britain and necessary authority given for the search of a suitable location in the southern highlands of India. Michie Smith undertook the survey of Palni and Nilgiri hills in 1883 and 1885, his observations covering both the requirements of transparency and steadiness of image during both day and night. But in 1884 the Astronomer Royal recommended that Pogson having accumulated large arrears in observations, saddling him with additional work connected with the new large equatorial would not be desirable -- "on Pogson's retirement, the question of establishing a branch observatory or removing the Madras Observatory to a more favourable station might be considered. I am disposed to prefer to latter alternative....."

The idea of making solar observations under tropical skies soon gained ground and the search for a suitable site extended over the entire Indian sub-continent. In the north, Leh, Mussoorie and Dehra Dun were examined for their suitability. In the southern part, the study was confined to Kodaikanal, Kotagiri and Madras. The Leh and Mussoorie observations indicated that the skies were seldom free of dust as to permit observations that called for high transparency. And so the new observatory had to be located in the southern hills with Kodaikanal becoming the obvious choice on the basis of performance. At the Indian Observatories Committee meeting of July 20, 1893 with Lord Kelvin in the chair, the decision was taken to establish a Solar Physics

Observatory at Kodaikanal with Michie Smith as its Superintendent, the decision on the permanent site of the Astronomical Observatory being deferred to a later date. The observatory was to be under the control of the Government of India instead of under the Government of Madras as it had been for a century earlier.

The Kodaikanal Observatory: The last five years of the nineteenth century witnessed a rapid transformation of work from the Madras observatory to Kodaikanal. The first observations were commenced at Kodaikanal in 1901 and these conformed to patterns in the "new astronomy", that were planned for the observatory. While the two observatories functioned together under the control of a Director at Kodaikanal, the astronomical observations at Madras were confined only to the measurement of time. The new observatory had a wide array of spectroscopic equipment specially acquired for solar studies. There were instruments to visually examine the prominences around the solar limb and the spectra of sunspots. Photographic studies included daily white light photography of the solar disc and monochromatic chromospheric pictures with the spectroheliographs in the light of ionized calcium and of hydrogen. This uninterupted series of photographs, continue unto the present day, and form one of the most unique collections of a record of solar activity available anywhere in the world. Only two other institutions, the observatory at Meudon in Paris and the Mount Wilson observatory have a collection that spans an equivalent time interval.

Perhaps the most important result of these early years was the discovery by Evershed at Kodaikanal in 1909 of radial motion in sunspots. In the next few years numerous studies of this phenomenon now known as the Evershed effect, were made both at Kodaikanal and at a temporary field station in Kashmir. These early studies have been so comprehensive that little has been added to our information on it in the subsequent half century. In 1922 Evershed also discovered under conditions of good seeing innumerable small displacements of lines equivalent to velocities of the order of a few tenths of a kilometre per second. Nearly fifty years later with better spectrographic and image resolution, extension of this early discovery have added much information on wave phenomena in the solar photosphere and chromosphere.

For the thirtyeight years between 1922 and 1960, the directors were Royds, Narayan and Das. The activity in solar physics was maintained at the pace it had been and work progressed in the traditions of the early years. Highlights of this era are the discovery of the oxygen lines in emission in the chromosphere without the aid of an eclipse, the centre-limb variations of the hydrogen lines and their use to study the solar atmosphere and the detailed study of the properties of the dark markings seen in H-alpha.

For studies of the physical properties of stars the observatory had limited instrumental resources. Nevertheless,

some interesting results on comets and stellar spectra were obtained that substantiate the concept that at any such institution the men who use the instruments are more important than the instruments. Soon after his arrival in 1907 Evershed discovered the ultraviolet tail bands in Comet Daniel that are now ascribed to CO^+. Evershed made numerous studies of the planet Venus and of Nova Aquilae 1918. And his dispersion spectra of Sirius have had the highest dispersion values employed in stellar spectroscopy until recently.

Astronomy in the Princely States: Since the Jai Singh era Royal patronage for astronomical effort was resumed only in the 19th and early 20th centuries. The king of Oudh had established an observatory at Lucknow around 1832. A mural circle of six feet, an eight feet transit, and an equatorial by Troughton and Simms formed the principle equipment. Some observations were made at this observatory by Wilcox who assumed charge of it, but after his death the observatory was closed down in 1849. The Maharaja of Travancore had founded an observatory at Travancore in 1837. A transit instrument, two mural circles and an equatorial telescope and magnetic and meteorological instruments formed the principle equipment of the observatory. But it is renowned principally for the magnetic observations made by Broun who was the director of the observatory from 1851 to 1865. His chief discovery is now one of the fundamental principles of terresterial magnetism that magnetic disturbances on the earth are not localised, but are world wide phenomenon. Broun is also

associated with the discovery of the relationship between solar disturbances and subsequent changes in the state of the earth's magnetism in recurrence intervals of 27 days. He also found that the magnetic disturbances proceed from particular heliocentric longitudes. Soon after Broun's retirement the activity of the observatory was greatly reduced in 1865 but the observatory continues to the present day.

Towards the last decade of the nineteenth century an observatory was started at Poona. Called the Maharaja Takhtasingji observatory, it commenced activity at Poona under the direction of Professor K.D. Naegamvala. A part of the nucleus of the funds that were needed for the starting of the observatory were provided by the Maharaja of Bhavanagar. The observatory had the largest telescope in the country, a twenty-inch Grubb reflector. It also had several smaller instruments, which were principally used for eclipse observation. The most important work that has appeared from this observatory has been the observations of the solar corona of 1898. The Naegamvala expedition to Jeur and the successful observation of corona and its spectrum described in Volume I of the Publications of the Maharaja Taktasingji observatory is the first complete Indian effort of its kind on record.

Astronomical research in the Universities: While there have been very limited efforts directly by the Universities to foster astronomical research, it is noteworthy that individuals from the Indian Universities have made very substantial contribution to general progress in theoretical Astrophysics. At the top of the list stands the pioneering contributions of M.N. Saha that forms the basic foundation for interpretative stellar spectroscopy. Saha's ionization formula revolutionized Astrophysics, for it enabled an understanding of the physical conditions in the stellar atmosphere. Saha's second important contribution has been his conjecture of the gains that will accrue to astrophysics from a stratosphere observatory. This stimulating suggestion represents the earliest thinking in a field that has come of age in the space era. Other noteworthy contributions in theoretical astrophysics by D.S. Kothari, S. Chandrasekhar, R.C. Majumdar, A.C. Banerji and his students make Indian effort in this area of the highest calibre.

The Nizam of Hyderabad established the Nizamiah Observatory in 1908 at its present location in Begumpet. The stimulus for this happening seems to have been the donation of two principal telescopes by Nawab Zaffar Jung Bahadur, one of the courtiers of the Nizam. The largest of these was a fifteen inch visual refractor which was mounted at Hyderabad in 1922. The observatory has been under the control of the Osmania University since 1919. The smaller instrument was an eight inch astrograph built by Cooke and it is with this instrument that the observatory participated in the great international programme of the "Carte-du-Ciel". The zones photographed at Hyderabad cover the declination belts +36° to +39° and -17° to -23°. Its first three directors, Chatwood, Pocock and Bhaskaran, supervised the gigantic work of preparation of the astrographic star catalogue. Twelve catalogues comprising observations of 8,00,000 stars were published. The study of comets, variable stars, lunar occultations and solar activity was also pursued at Hyderabad. The availability of a spectrohelioscope in the mid-thirties and a blink comparator extended the sphere of activity of the institution. Proper motions studies of stars in the Hyderabad astrographic zone were commenced. Since 1944 when Dr. Akbar Ali became the director of the observatory, a programme of double star measurements formed an important addition to the activity. Akbar Ali's principal contribution to the observatory was the subsequent acquisition of a fortyeight inch reflector for the observatory, but this development which started in 1957 falls beyond the purview of the present account.

Total eclipses of the sun: Three total eclipses with paths of totality across India are memorable events in the history of astrophysics. The first one of August 18, 1868 created the subject of solar physics, for at this eclipse the spectroscope was used for the first time to discover the gaseous nature of the prominences. The hydrogen emission lines seen in the prominence were so strong that the French astronomer Jansen reasoned they could be seen without the eclipse. The next day at the eclipse site the speculation was proved to be correct, making it possible for daily surveys of prominences thereafter, without the need of a total eclipse.

There were several eclipse teams scattered over the path of totality for this vital eclipse. The Madras Observatory had two teams, one at Wanarpati and the other at Masulipatam. Clouds at Wanarpati interfered with the success of the expedition. At Masulipatam Pogson detected the hydrogen lines in emission, as had all the teams that had a programme of observation with the spectroscope. They also saw a bright yellow line near the position of the D lines of sodium. The line originated from a hitherto unknown element later termed helium after the source of its earliest detection.

The eclipse of December 12, 1871 had a path of totality passing over Ootacamund and Pudukotai near the southern tip of the country. Jansen at this eclipse reported the discovery of dark absorption lines in the coronal spectrum. This was the occasion when, what we now term the F-corona, was first seen.

On June 6, 1872 an annular eclipse was visible at Madras. Pogson examining the region close to the moon's limb found the bright chromospheric spectrum flash out for a short duration on the formation and again at the breaking up of the annulus. This is the first observation on record of viewing the flash spectrum at an annular eclipse.

The next important eclipse in the Indian region was the well observed one of January 22, 1898. Numerous expeditions from different countries, were scattered all along the path of totality from Ratnagiri to Sahdol, in former Vindhya Pradesh. The Kodaikanal Observatory instruments were at Sahdol and a fine series of white light photographs of different scale were obtained.

At Jeur, Naegamvala had organised a very comprehensive study of both the chromospheric spectrum and the corona. The report of this successful expedition indicates the great care and thoroughness that went into the planning of the expedition.

During the twentieth century there were no total eclipses of the sun visible from India. Nevertheless, the Kodaikanal Observatory sent out an expedition in 1922 to Australia to measure the deflection of starlight in the sun's gravitational field, an important aspect of Einstein's theory of relativity that could be experimentally verified. The expedition was a total failure, a result of dependence on equipment of bad workmanship taken on loan, that even Evershed's wizardry could not rectify. Royds was deputed to the eclipses of 1929 in Siam and 1936 in Japan.

Role of amateurs in India: Astronomy is a subject where activity by amateurs has often led to significant contributions to the subject. While such efforts in India have not been on the same scale as in the Western countries, they have nevertheless played a significant role.

The earliest of such activity on Indian soil in recent times can be ascribed to the Jesuit priests. The first recorded use of a telescope is by Father Richaud at Pondicherry who in December 1689 discovered a comet and also that Alpha-Centauri was a double star, the fifth such object to be known at the time. Since then during most of the nineteenth century there have been sporadic efforts of amateurs at observing solar eclipses and rare events like the transit of Venus. It is Nawab Zaffar Jung's interest in astronomy that led him to acquire a whole array of telescopes, which later formed the principal instrumentation of the Nizamiah Observatory. At Vizagapatam A.V. Narsing Rao with a six-inch telescope made observations of the transit of Venus and Mercury as well as of many bright comets.

The introduction of celestial photography ushered in a new era in variable star discovery. There were numerous variables discovered each year and preliminary efforts could soon indicate from the light curve the nature of the light variation. The class of long-period variables were particularly well suited for amateur studies with small telescopes since a large number of individuals observing a chosen set of three to

four hundred such stars could ensure good continuity of observation for the light curve derivation. The novae and catacylsmic variables came under such scrutiny as a result of which we have continuous light curves available since the first decade of this century of most of these stars. The pioneer of such study in India was R.G. Chandra of Bengal, who from 1919 until the late forties was a regular contributor each month to the American Association of Variable Star observers (A A V S O) located with its headquarters at the Harvard Observatory, Cambridge, U.S.A. Chandra's earlier observations were made with a three-inch refractor owned by him. He was later loaned a splendid six-inch Clark refractor by the AAVSO to extend his observations to the fainter stars. Another who came on the scene in 1927, was M.K. Bappu of Hyderabad who contributed many thousand observations regularly to the AAVSO and the Variable Star Section of the British Astronomical Association.

A sphere of endeavour particularly suited for study by amateurs has been the visual observations of meteors. It is only in recent years that photography by very fast cameras and radar-echo studies have been the principal means of acquiring information on these objects. In the earlier epoch the visual observer's information gave us all the statistical information on meteor showers and radiants. And the single Indian observer most prolific in making these observations was M.A.R. Khan of Hyderabad. Khan's observations were contributed to the American Meteor Society and for many years he was their outstanding observer.

Amateur activity is generally fostered by astronomical societies formed by amateur groups. The example given earlier like the AAVSO were international in scope, with a substantial membership of American origin. And in turn the impact made on astronomical growth in the country is considerable. Efforts at formation of such a grouping led to the formation of an Astronomical Society of India in 1910. The society functioned for over a decade on the lines of the British Astronomical Association with different sections for the study of variable stars, meteors, and the Moon. It published a journal and had a few telescopes of its own used by members for carrying out observations of interest. One of the members who functioned as Director of the Variable Star section of the Society was C.V. Raman who later discovered the well known effect in optics named after him.

One of the most interesting of amateur effort encouraged by societies has been the grinding of telescope mirrors, and in this case too the Indian society was no exception. Its journal records several accounts by members, of the procedures they adopted for grinding mirrors upto even sixteen inches apertures by hand.

The largest aperture paraboloid, made by an Indian prior to 1947, was H.P.Waran of Madras, who used a grinding machine fabricated by him for the purpose. The mirror of twentyfour inches aperture was the primary of a reflecting telescope that could not be completed due to paucity of funds.

As an example of interests that are acquired as an amateur, which later become professionally oriented, one can mention the existence in 1910 of the firm of S.K. Dhar and Bros., of Hooghly, who manufactured mirrors for reflecting telescopes.

Postwar plan for astronomical development: A committee appointed by the Government of India, with M.N.Saha as Chairman, examined in 1945 a plan for the development of astronomical research and teaching at the existing observatories and in the Universities. The recommendations made by this committee include (i) the establishment in North India of an astronomical observatory with a telescope of large aperture (ii) the extension of facilities at the Kodaikanal Observatory by the availability of a coronagraph, solar tower telescope, large aperture Schmidt telescope and a laboratory for solar terrestrial studies (iii) the establishment of a Naval Observatory and a Nautical Almanac section (iv) the need for postgraduate teaching in astronomy and astrophysics at the Universities of Delhi, Aligarh and Benares, where observatories with fifteen-inch aperture telescope were to be provided. Much of the committee's recommendations, especially in so far as the Kodaikanal Observatory is concerned have borne fruit in subsequent years; however, it is of interest that astronomy has been a subject that was given importance, in the general deliberation of postwar planning.

M.K.V. Bappu