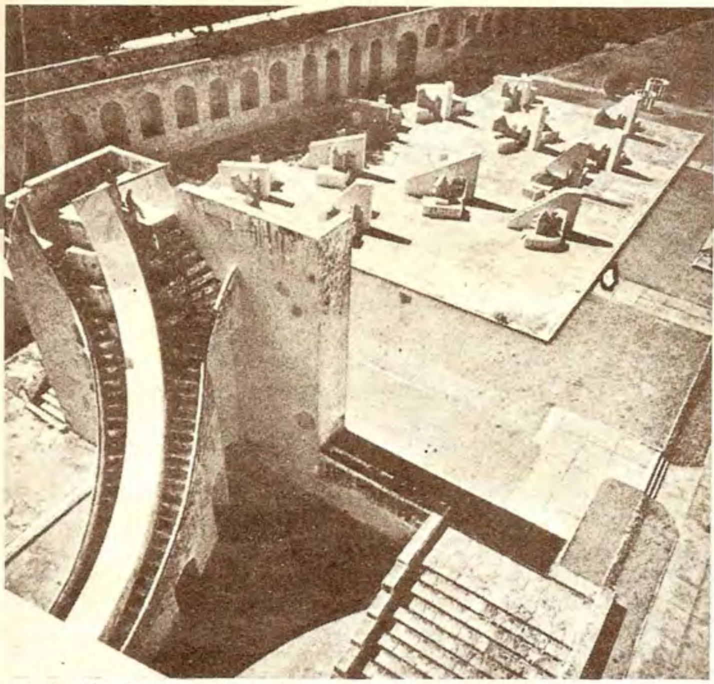


Jai Singh's observatory in Jaipur

THE ROAD TO KAVALUR

J C BHATTACHARYYA

IN THE northern cities of Delhi, Ujjain, Banaras, Mathura and Jaipur stand the ruins of five magnificent observatories. Built by Raja Sawai Jai Singh II, the 18th century ruler of Jaipur, these immense observatories, more accurate than those of Samarkand, are also monuments to a tragic error of judgement. Largely oriental in design and concept, they didn't allow for a European invention that by then had greatly increased the range and accuracy of observatories in the West — the telescope.

It isn't merely time that separates Jai Singh's observatories from the new one at Kavalur, it's a change of attitude. Intelligent and far-sighted as Jai Singh was, he wasn't far-sighted enough to realise the importance of the telescope. (It is known that he tried to instal telescopes in his observatories but ultimately decided in favour of huge masonry structures on the lines of the instruments developed by Ulugh Beg, the Central Asian king.) So, in a sense, his observatories were obsolete even before they were set up.

Not so the Kavalur observatory which, despite rapid advances in astronomical observation techniques, is designed to stay in the front line of astronomical research. The result of decades of international co-operation and dedicated local effort, its 93-inch (236-cm) telescope, the largest in Asia, will gather information beyond the reach of our present observatories in Kodaikanal, Hyderabad, Ooty and Nainital. Because of it, Indian astronomy may well be on the threshold of a great leap forward. Those who worked towards it have reason to be proud of the achievement.

Who were the men who made it possible and why was Kavalur chosen as the site for the project?

Two personalities stand out, M N Saha and M K Vainu Bappu, but to tell the story of Kavalur (and the growth of astronomical observation in India) it's necessary to look at a period a little before them.

Although telescopes did not find a place in Jai Singh's observatories, the French Jesuit priests of Pondicherry had already used them at the end of the 17th century. In December 1689, Fr Richaud announced the sighting of a comet through a telescope. The merchants of the British East India Company also brought similar instruments to India. In 1792, they established an observatory in Madras; among its many instruments were two 3-inch (7.5 cm) refractors.

The Madras observatory had a transit instrument and it was mounted on a big granite pillar on which an inscription in Latin, Tamil, Telugu and Hindustani proudly announced: "Posterity may be informed a thousand years hence of the period when the mathematical sciences were first planted by British liberality in Asia" (One can still see this pillar in the courtyard of the present Meteorological Office at Nungambakkam in Madras.)

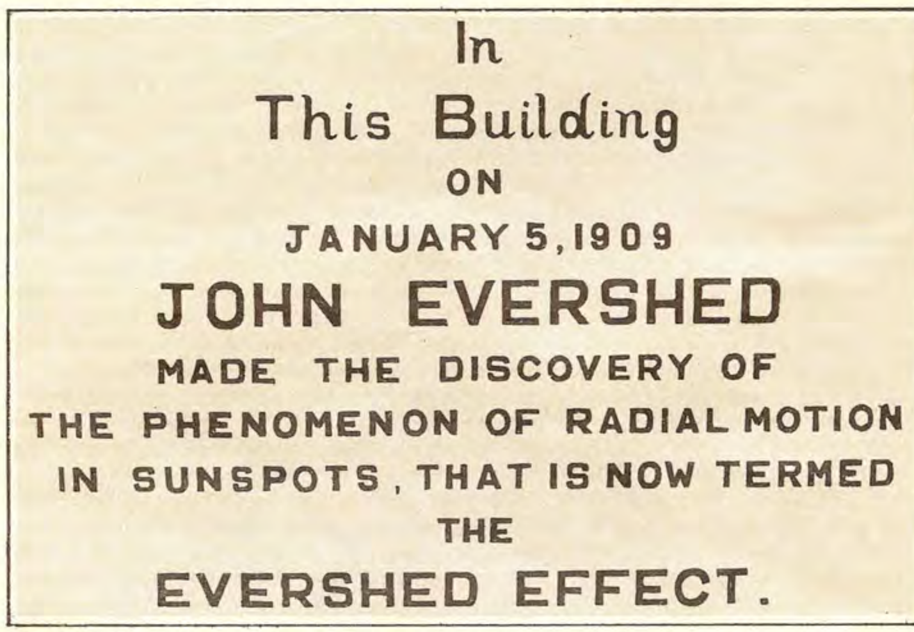
The Madras observatory functioned for more than 100 years and it carried out important astronomical observations. Asteroids Asia, Sylvia, Sappho etc were first discovered by N R Pogson from this observatory. Work on variable stars was also done and the variable nature of several stars was studied in detail. In 1865 a bigger 8-inch (20 cm) refractor was installed and through it, C Ragunathachari discovered the variable nature of a star R Reticuli in 1867. This appears to be the first major success by an Indian astronomer using telescopes.

In 1899, there was an important change in the observatory's set-up. The scope of studies was expanded to new astrophysical studies of the Sun and the observatory was shifted to a high mountain peak in South India. This marks the beginning of another glorious period. The Kodaikanal Observatory immediately made important contributions to studies in solar physics. John Evershed personally built up several new instruments for solar investigations. Using one such instrument he discovered a new finding of the solar atmosphere: huge vortical motions of gases, surrounding sunspots. His discovery has been commemorated on a marble plaque in the observatory.

Evershed wanted to extend the observatory's activities in stellar research also, but the unstable night skies of Kodaikanal came in his way. He had discussed these problems with government authorities and following their advice, undertook a search for a better location. He conducted an elaborate survey in Kashmir and also selected the site for the new observatory. But his plans were upset by the First World War. That was followed by a worldwide economic crisis and even before the country could tide over those difficult days, humanity was plunged into the Second World War. During the later stages of this war, some post-war development schemes were formulated, and the idea of a proper astronomical observatory was reborn in that phase.

In the third decade of this century, Indian intellectuals supporting the nationalist movement demanded more freedom. As a partial fulfillment of the demand the Council of Scientific and Industrial Research funded from Central Revenues was created. Even before this, a few research institutions were pursuing pure research despite severe financial difficulties. Among them the Indian Association for the Cultivation of Science in Calcutta stood supreme. Now, under more affluent conditions, was established the Tata Institute of Fundamental Research (TIFR) in Bombay. A few more scientific institutions were established in different parts of the country and to estimate the requirements for astronomical research, a committee was formed, with Prof M N Saha as its chairman. The committee consulted almost all the leading scientists in India and made recommendations. The recommendations included several suggestions for improving the existing observing facilities. It was also emphasised that efforts had to be made to establish a fairly large observatory so that the scientists of India could do astronomical research independently.

Madras observatory 1792



Evershed plaque

When it was time to carry out the recommendations, political changes had already taken place in the country. The elders were keen on bringing back the glorious past of India by encouraging the re-establishment of ancient science institutions. There was a suggestion that the new observatory be established at Ujjain, a centre of old Indian astronomical studies. A survey team was sent to examine the observing conditions. After two years of observations their findings showed that the amount of clarity and stability of the atmosphere needed for the use of modern astronomical telescopes was totally lacking over Ujjain. A big observatory could be established only after a more detailed search.

The person responsible for this investigation was the Director of the Kodaikanal observatory, A K Das. At that stage he decided that priority be given to those recommendations of the Saha Committee which could immediately be carried out. The solar observing facilities at Kodaikanal underwent elaborate changes. The famous telescope makers of England, Grubb Parsons & Co, supplied a new solar telescope. A special instrument — a Lyot filter for studying the chromospheric layers of the Sun — was imported from France. In the International Geophysical Year 1957-58 the Kodaikanal observatory took on the huge responsibility of covering the big gap of observations between Manila and Rome. The task was completed and immediately afterwards, because of his age, Dr Das had to retire. He then took over the directorship of Nizamiah observatory but could not continue for long. His health deteriorated and he never recovered. He died a year later, in1961.

Astronomers, however, did not forget his contribution. At the 14th meeting of the International

Astronomical Union at Brighton, when a decision was taken on naming the newly discovered craters on the far side of the Moon after late scientists of eminence, his name figured as one of the venerables.

His place was filled by a young scientist, M K Vainu Bappu. It is impossible to describe the present growth of Indian astronomy without mentioning his monumental contribution. His uncommon devotion, far-sightedness and scientific achievements adorn the present chapter of the history of Indian astronomy.

Vainu Bappu's ancestors originally hailed from the Malabar region of the West coast of India, but he spent his childhood and early youth in Hyderabad. His father was an astronomer in Nizamiah observatory, Hyderabad; Vainu Bappu's first lessons in astronomy were under his watchful eyes. His first scientific paper was published when he was 16 years old. It was a study of a variable star. Also by this period he had collected material for another paper on the spectrum of night air glow. He had built the spectrograph he used with his own hands, and exposed the photographic plate for several nights through his bedroom window to get this remarkable observation.

Kodaikanal solar tower telescope

Kavalur 93-inch telescope

Vainu Bappu got his master's degree in physics in 1948 and came to a critical juncture in his life. He was set on studying astronomy but no facilities existed in the country at that time. Studying abroad involved huge expenses not within his reach. He obtained a scholarship for research on the subject of telecommunication and was hesitating whether to go ahead with it when another opportunity presented itself to him. The famous American astronomer Harlow Shapley was in Hyderabad at that time, and Bappu took a chance of meeting him at his hotel. He made an immediate impression and Shapley helped the young man go to Harvard.

At Harvard, Bappu immediately started working on the new instruments available to him. In January 1949 his efforts were rewarded by the discovery of a new comet. (It came to be called Comet Bappu, Bok and Newkirk.) The discovery was accidental. Bappu himself pointed to the existence of the uncommon object on the photographic plates taken on the previous night. Then, with the help of his colleague Gordon Newkirk and his Professor Bart J Bok, he confirmed his finding. From several of Bappu's plates taken on successive nights they computed the new comet's orbital parameters. Even to this day this is the

Why Kavalur?

WHAT POINTS of a site need to be examined before establishing a big observatory? The first thing is to find out the amount of clouding in a promising area. (This can be done from the records of the meteorological office. The records for the exact site, of course, are not normally available; so one has to rely on records obtained at nearby stations.) After this preliminary selection, touring observing teams carry out detailed examinations. Such teams usually have small telescopes with them; they note down the weather conditions, the clouds, and above all the stability of the atmosphere at the site. This is usually done by measuring the seeing disc in a small portable telescope. It is absolutely necessary to have some idea of the "seeing" quality of the site. Meteorological studies may show that the climate of two places close by may be similar while astronomical seeing may vary — the latter depending upon the immediate environment. Ground cover or the unevenness of a site influences this factor greatly. Visibility is usually good in valleys surrounded by high peaks. If the surrounding ground is covered by dense vegetation, which prevents sunlight from heating the ground, the seeing is usually good.

Some good locations are situated in the midst of lakes. These are particularly good for solar studies where observations have to be continued with the Sun high up in the sky. A solar observatory in California — the Big Bear Lake Observatory — has been established on a big lake located high up in a mountain. Its excellent records fully justify the siting. Such an observatory has also been established at Udaipur on a small island in Fateh Sagar lake.

The third requirement is that the site should not be close to large industrial centres or urban populations. Air pollution, caused by industrial or domestic smoke and the scattered light from illuminated areas are a major hazard. The surroundings of Mount Wilson are an example. Almost the entire Western sky of this observatory is flooded with the lights of Los Angeles. Astronomers at this observatory admit that the only time good work could be done there was during the Second World War, when the skies above the city used to be dark during black outs.

The other requirements are good roads, transportation, human habitation nearby, and minimum facilities like schools and hospitals not too far away from the site. Large urban centres of population are also avoided because of their tendency to grow rapidly. (When establishing an observatory, some astronomers piously hope that the installation should keep its privacy for a few centuries!)

Almost all the conditions have been reasonably satisfied at Kavalur: The skies of southern India are relatively free from dust; although the clouding is somewhat greater than elsewhere it is seen that the south-eastern part of the Deccan is comparatively cloud-free. The observatory of Kavalur is located in this area. By virtue of its location between the two hills of Javadi and Elagiri, there is a characteristic stability of the lowest layers of the atmosphere; this reduces turbulence. The forest department takes special care to maintain the valuable sandalwood forest; there is hardly any chance of its demolition in the near future. Good roads and electricity exist in this area. The site is almost equally distant from Madras and Bangalore and is just three to four hours away from the two cities. Just 12 kms away from this observatory is a small township, Alangayam, where the basic necessities of living exist.

For the setting up of the buildings housing the telescopes, a small portion of the original forest had to be cleared, but new trees were planted in the cleared areas to provide adequate ground cover. On entering the campus one finds a small grove of arecanuts, beyond which stretch a number of fruit-bearing trees. The roads are lined by bougainvillea and poinsettia plants, very colourful during their season. The flowering of gulmohr, cassia and jacaranda also contrast wonderfully with the white telescope domes.

Visiting Kavalur observatory, an American astronomer remarked: "Every observatory has got a nick name; I think Kavalur observatory should be called the garden observatory." A still better description has been given by a senior Indian scientist. After seeing the observatory he remarked that a truly traditional Indian hermitage had been created in the forest to study the noble science of astronomy.

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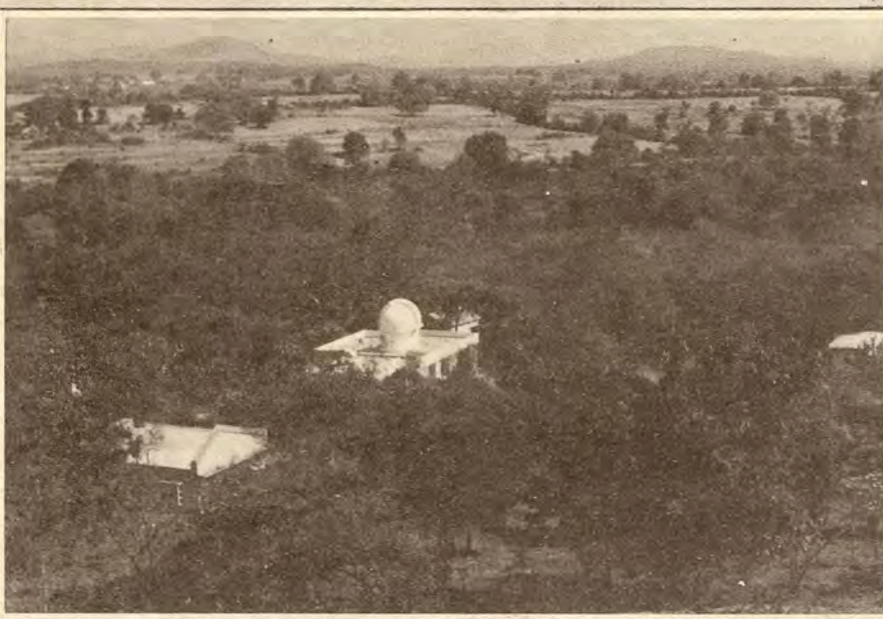


Kavalur observatory

only comet which bears the name of an Indian scientist.

(It is interesting to note that along with the congratulations Bappu received, there was a letter from his sponsoring organisation in India. It advised him not to waste his time discovering comets and to concentrate more on his studies. The Astronomical Society of United States, however, specially honoured him for his discovery.)

In 1952 Bappu got his doctorate from Harvard University on the subject of stellar spectroscopy and immediately got an offer from Hale Observatories of Pasadena, California. The offer meant a chance to work with the largest telescope in the world at that time, the Palomar 200-inch. He joined the institution as the first Indian Carnegie Fellow. Two years later came one of his biggest discoveries — an unknown effect in stellar chromospheres. In collaboration with Olin Wilson he discovered what came to be called the "Wilson-Bappu Effect". A completely new method of probing the mysteries of the outer layers of the stars was developed.

Bappu returned to India in 1953 and got an offer to build up a new observatory in Uttar Pradesh. With the help of Sampurnanand, then Chief Minister of UP, he established the new observatory at Manora Peak in Nainital. Modern instruments were installed in this new observatory and a school of young astronomers developed under his guidance. In 1960 he handed over the responsibility for this observatory to this young group and took charge of Kodaikanal, the biggest observatory in the country. He was then only 32 years old.

The most important of the recommendations of the Saha Committee had still to be carried out. Bappu diverted all his attention to do this. His main aim was to build up a big observatory which could match any other in the world. To start with, he decided that the new observatory should not be in Ujjain, but somewhere as far south in the country as posssible. From such a location the newly discovered enigmatic objects of the southern sky would be within the instrument's reach, so a location in northern India would not do. Bappu reasoned that if we wanted to go in for modern astronomical research without huge financial investments, we had to

Different kinds of telescopes and their uses

IT IS said that Hans Lippershey of the Netherlands discovered the telescope by accident. The use of spectacles for helping defective vision was common in those days — the artisans of Venice had built up a considerable reputation as lens makers for spectacles — and Lippershey was the owner of a shop dealing with such lenses. One day he noticed that a combination of two spectacle lenses brought distant objects nearer. He built up the first instrument with two lenses within a tube and the first telescope was produced. He even managed to sell some pieces to the Dutch navy for help in their operations.

Galileo heard about the developments and he set about making a telescope ali by himself. He completed the instrument and started examining the objects in the sky. The results astonished him. The objects he focused on revealed a completely new picture. The Moon's surface was found to be a wasteland full of craters. Rows of dark spots were seen over the brilliant disc of the Sun. The bright face of Venus unfolded its beauty of changing phases; the planet Jupiter was seen to be surrounded by satellites; Saturn was seen to be encircled by rings and the hazy nebular patch of the Milky Way revealed the presence of millions and millions of stars. For the first time, the telescope revealed that the planets are nothing but material bodies like our Earth all following some universal laws of motion. All mythological links to the gods and goddesses snapped; the simple old beliefs of ancient mankind lay shattered through the observations of one single instrument.

By today's standards, the telescope introduced by Galileo was not much more than a toy but the significance of his discoveries was revolutionary. Later, much larger and more powerful telescopes were developed in different parts of the world. The scientific analysis of the physics of formation of images unfolded many new facets of the mysteries of light. Sir Isaac Newton introduced the use of the concave mirror, the new type of instrument using the principle of reflection of light. The evolution of this instrument ultimately provided astronomers with a most powerful tool of observation.

The main part of the telescope is a big concave mirror or a lens, which collects light over a large area and creates a bright image. This part is known as the "objective". The concave mirror constitutes the objective of a reflector telescope while a combination of lenses forms the objective of a refractor telescope. The main purpose of the telescope is to collect light from faint distant objects and create bright, clear images in its focal plane. In the history of the evolution of telescopes both these types of instruments developed side by side. Depending on the field and stage of development of technology, one or the other alternately held dominance. Galileo's telescope was a refractor type. It was Newton who introduced the reflector type. The rapid development of the latter took place from the time of William Herschel in the late eighteenth century. The use of more than one reflector greatly increased the versatility of such telescopes, and very large objective mirrors began being used. In the 19th century, refractor telescopes once more took the lead but ultimately the race was won by the reflectors.

In the beginning of the present century, with the construction of the 100-inch telescope at Mount Wilson, the reflector types have advanced quite far beyond the refractors. At present the biggest refractor is in Yerkes Observatory near Chicago. Compared to the large reflectors available at different observatories, this 40-inch telescope is very small. The biggest reflector of today is at Zelenchukskya in the USSR, whose objective spans a size of 6 meters or 234 inches. The next biggest is the Palomar 200-inch telescope. Established in 1948 it remained the biggest telescope in the world for 30 years At present the biggest telescope in Asia is the 74-inch instrument in Tokyo. That first place will go to Kavalur when its 93-inch telescope is completed.

The biggest advantage of telescopes is that they make very faint objects visible. There is a limit to the faintness of a star which we can see with the naked eye; the use of telescopes extends this limit several million times.

In order to fully understand the reason for this, some idea of the brightness of celestial bodies is necessary. In ancient times, the Greek astronomer Ptolemy had grouped all the visible stars into six different classes. He introduced a new unit for measuring brightness — "magnitude" — and stars of the first magnitude were the brightest. Those of the second magnitude are relatively fainter and in this way the faintest stars visible to the naked eye were classified under the sixth magnitude. Ptolemy's classification was totally subjective. In the middle of the 19th century it was proved that human perception of light or sound depends on a ratio of their intensities.

Milton looking through Galileo's telescope attack the problems connected with the southern sky. Objects of the northern sky had already been studied by big instruments. Any new discoveries in that area would need highly sophisticated arrangements which could perhaps wait for a later occasion.

Carl Zeiss of East Germany got the order for the new telescope and Bappu set out with a group of young men to look for a suitable place. The entire area from Kanyakumari to the hills of Tirupati was searched. After three years it appeared that a site in the Javadi Hills, among a dense sandalwood forest, was perhaps the most suitable. The project was named after a small village nearby — Kavalur. The observatory came into existence in early 1967.

The first installation there was a 15-inch reflector telescope which had been completely built in the laboratories of the Kodaikanal Observatory. Work began on the observation of several variable stars. At the same time, the observations for determining seeing conditions over Kavalur were continued — a test which is

This point can be illustrated by an example. Let us assume that we have a ground glass screen behind which there are a number of small lamps of equal brightness. These lamps can be individually lighted or extinguished. When lighted they illuminate the front glass screen whose brightness depends upon the number of lamps lit. If only one lamp is lit, there will be a faint illumination on the screen. If we light another, the brightness will increase and our eye will be able to perceive this change. Now if we want to bring about exactly another step of equal change as judged by our eye, we have to light two lamps, not one. But if the screen is illuminated by 50 lamps, one, two or five more will hardly make any perceptible change in the brightness of the screen; we will have to

Newton's telescope

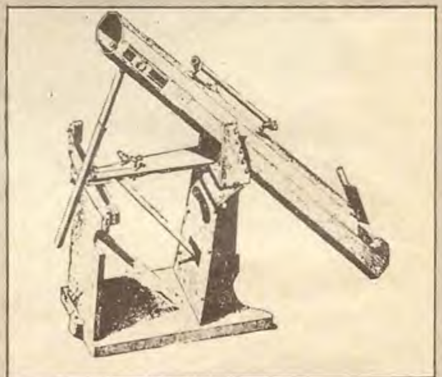
light 50 more lamps to bring about a change which, in our judgement, will be the same as was created when the illumination was increased by lighting one to two lamps. The reason is physiological. Our perception follows not the intensities, but their logarithms. If we go on increasing the illumination at a uniform rate, it will appear non-uniform to the human eye. But if the rate of increase is kept so that the logarithm of the total light flux increases uniformly, the increase will appear smooth. This principle was proved by two physiologists, E M Weber and Fechner.

Immediately after the publication of their paper, the astronomer Norman Pogson gave a mathematical formulation of Ptolemy's magnitude scale. Incidentally, Pogson spent the last 32 years of his life in India, as the Director of Madras observatory. He showed that the subjective classification of Ptolemy was made according to the logarithm of their brightnesses, obviously without his knowledge. The stars of the first magnitude are almost 2½ times brighter than those of the second magnitude. The difference in the decimal logarithms of these two numbers is exactly 0.4. The same rules apply for 2nd/3rd, 3rd/4th magnitude etc. Accordingly the difference of logarithms of brightness between a star of the sixth magnitude and the first magnitude is $5 \times 0.4 = 2.0$. The plain meaning is that the first magnitude star is 100 times brighter than a sixth magnitude star.

There are innumerable stars which cannot be seen by the naked eye. But their brightness can also be expressed on the Pogson magnitude scale. According to this scale a star of the 11th magnitude is 1/100th as bright as that of the 6th magnitude; a star of the 16th magnitude is 1/10000th as bright and one of the 21st magnitude a millionth as bright. Telescopes can bring all of them within our visible range.

It is not difficult to understand how this is achieved. Whenever we look at a star, the iris diaphragm of our eye opens completely and the total amount of light falling on the aperture focussed by the corneal lens on to our retina is what makes the star seem bright or dim. The size of the objective of the telescope is much bigger, so its ability to collect light is greater. It is possible to estimate this gain in a simple way. When completely opened the diameter of the iris is about 8 mm; the 8 cm diameter telescope is 10 times bigger, its light collecting area is 100 times larger and, therefore, it produces an image which is 100 times brighter than that incident on the retina of our unaided eye. This implies that such a telescope will enable a 11th magnitude star to be seen; extending this calculation it is apparent that an 80 cm telescope will show all 16th magnitude stars and the largest telescope in the world will make a 20th magnitude star visible.

Of course, very few persons have a chance of seeing the faint objects through a big telescope used for astronomical research, because its focal plane always contains photographic plates or photoelectric detectors for studying and recording brightness, spectra etc, and their



Hadley's telescope

variations. But at the time of setting the instrument, sometimes it is necessary to have a look at the object by using another small set of lenses called the "eye piece". Any person who has seen these objects through a telescopic piece more often than not gets hypnotised by the beauty of the faint objects.

Another great advantage of the telescope is that if the object is extended, its angular extent increases many times over. Galileo's telescope scored over the older instruments because of this; the expanded images of planets revealed their actual forms. The diameters of stars cannot be measured and there are special reasons for it but many binary systems in which the two stars revolve round each other but appear as a single bright point to the naked eye can be clearly seen as two separate stars through the telescope. Watching such systems over years has proved that the laws of mechanics hold good for distant stars also. Physics is really universal.

This significant advantage enables very precise measurements of positions and movements of the planets, and this knowledge was very important for astronomers of the middle ages. Jai Singh had to construct huge edifices just to be able to measure positions and movements more accurately.

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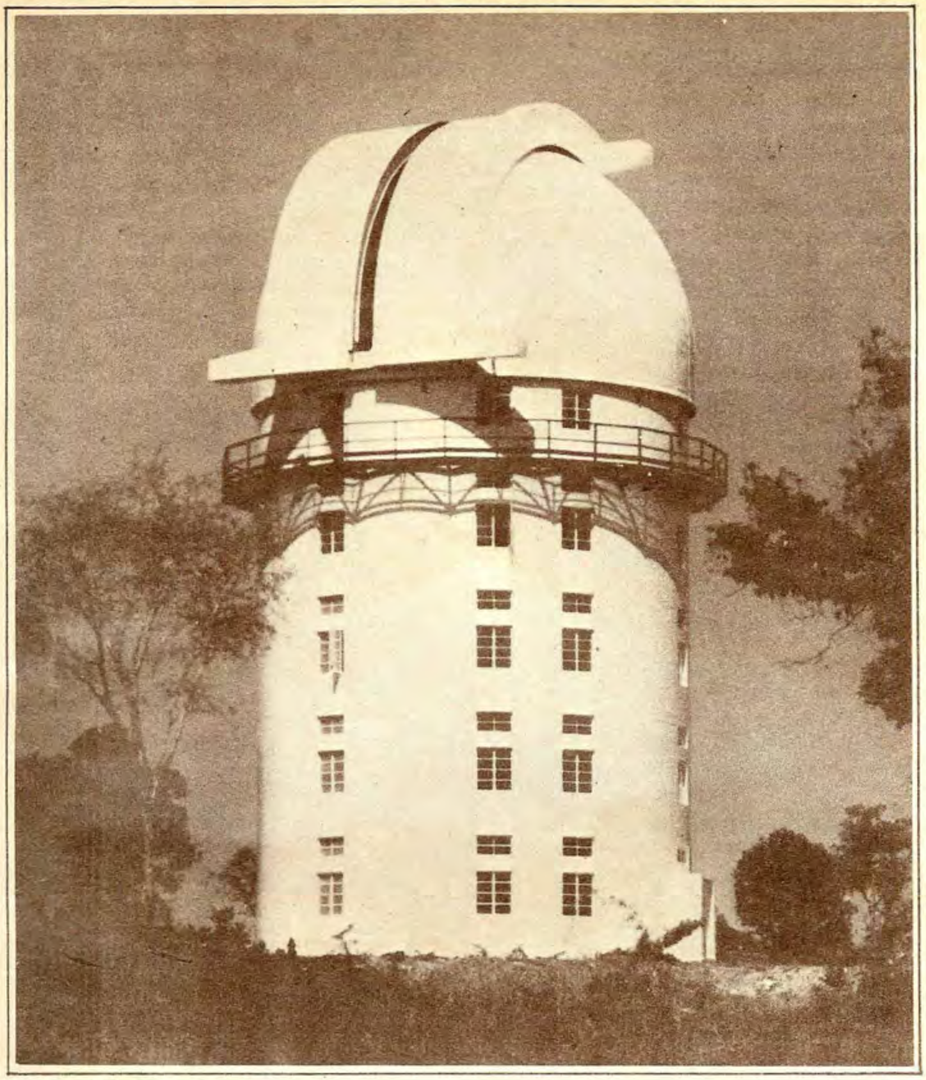

Kavalur 40-inch telescope

essential before installing a large telescope at a new site. After two years of observations it was found that the preliminary selection was justified, The sky over Kavalur is remarkably quiet. In 1969, the constructional work for a 40-inch telescope towei was begun. It was the first definite step towards realising Saha's dream.

The story after this is much more detailed, but only some highlights need to be presented here. The 40-inch telescope was installed in May 1972, and the very next month, during an occultation event, scientists obtained very valuable data on Ganymede, the third satellite of Jupiter. There was a still more momentous discovery on March 10, 1977, when the telescope detected the first indications of an extended ring structure around Uranus. In 1979, this telescope was used by two leading physical laboratories in India, the TIFR, Bombay and the Physical Research Laboratory (PRL), Ahmedabad. Their joint efforts resulted in the discovery of the first infrared bursters. Many small unknown details of our universe have been unfolded by observations with this telescope within a short span of less than 15 years.

Such achievements need a lot of effort in the preparation of facilities and that story usually remains untold. The engineers of Carl Zeiss came and established the telescope but setting up the other observing facilities was done entirely by the scientists of the Indian Institute of Astrophysics. This part of the elaborate development programme was personally shouldered by Bappu, in spite of his multiple responsibilities in the sphere of national and international commitments. Many new instruments were being built in the laboratories and one by one they were integrated with this telescope. High gain photomultipliers were employed to study faint objects. For the analysis of the faint spectra new spectrum scanners controlled by on-line computer were installed and many other powerful optical set-ups backed by electronics image intensification and data handling devices were brought into use. All known methods for analysis of faint light sources were incorporated in this unique installation in India. The facility available at Kavalur can match any other observing system employing a telescope of similar size anywhere in the world.

Now the latest observational facility has been set up and is in the process of being commissioned. This was Bappu's life-long dream. It is a matter of extreme regret that he did not live long enough to see it realised.

A powerful telescope, as recommended by the Saha Committee, has indeed been built and set up in a dome adjacent to the existing one metre telescope. The project of indigenously building up this gigantic equipment was conceived by Bappu and laid down in great detail. The telescope was to have as large an aperture as possible and was to be built entirely in the country; after assessing our technological capabilities the size was fixed at 93 inches, slightly less than the legendary 100-inch telescope at Mount Wilson. It was to have all the possible focal configurations: the powerful prime focus, where the astronomer will ride on a small cage high up in the telescope; a conventional cassegrain focus with a range of modern computer-controlled instrumentation, and a long focus high magnification coude configuration where experiments aiming at extreme high resolution observations would be possible.

To achieve these objectives, the help of many laboratories and industries in India had to be sought. The latest techniques in mechanical fabrication, control system engineering, hydraulics, cryogenics, electronics and computer sciences and a host of other specialised branches in science and technology had to be employed to produce this modern scientific observing system. Today the massive white dome stands atop the greenery of the surrounding sandalwood forest and symbolises the vision and aspirations of two of our great scientists whose dreams have finally come true.

Prof Bhattacharyya, director, Indian Institute of Astrophysics, Bangalore, has been associated with astronomical research since the late fifties. He has a D Phil from Calcutta University and has specialised in instrumentation and techniques for astrophysics. The best known of his achievements is the discovery of the rings of Uranus in 1977.