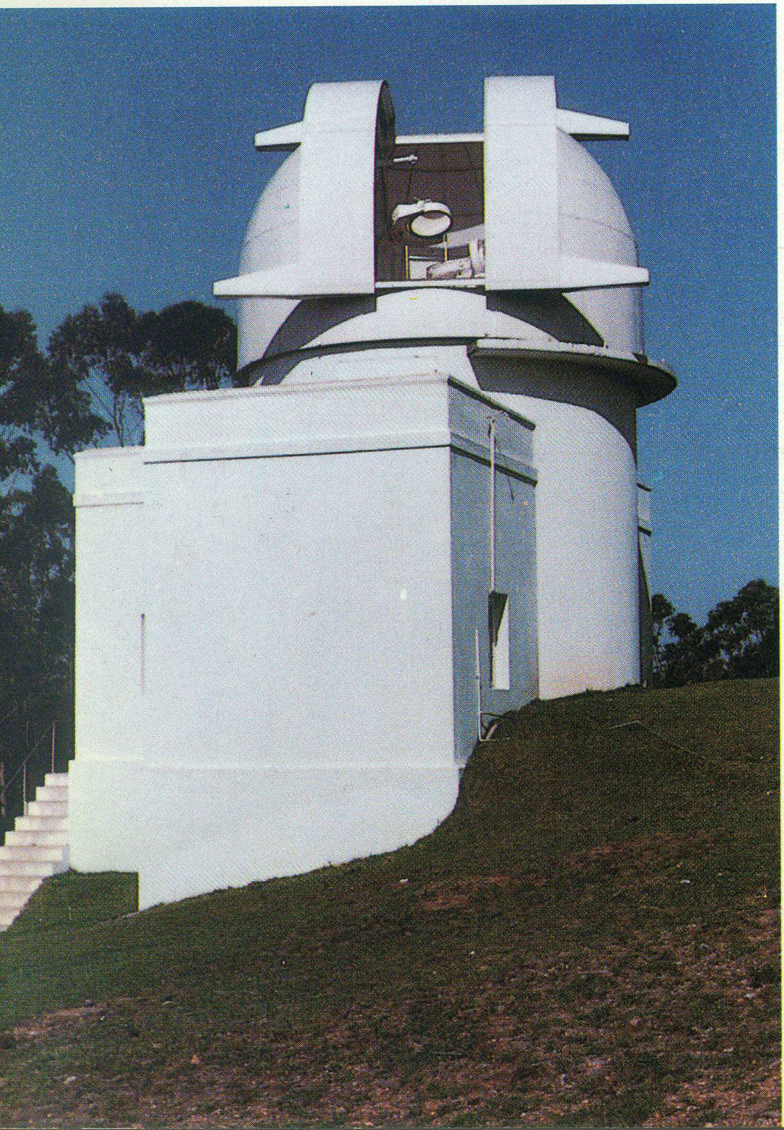
INDIAN INSTITUTE OF ASTROPHYSICS

The solar tower telescope at Kodaikanal, seen from the east



Jawaharlal Nehru at the northern end of the telescope on 5 October 1961. To his left is M. K. Vainu Bappu.

Front cover

The dome of the 2.3 metre Vainu Bappu telescope at Kavalur, seen from the west.

Astronomy is the oldest scientific discipline humankind has known. Ever since man learnt to walk upright, he has looked at the skies and wondered. His desire to understand the cosmic environment and put this understanding to practical use led to the development of astronomy.

The earliest impetus to astronomy came from the down-to-earth problem of keeping time, of making a sensible calendar. Astronomy was resurrected in the medieval times to meet the requirements of men at sea who wanted to know where they were and in which direction they were headed.

Invention of telescopes — spyglasses as they were called — in the early seventeenth century revolutionized our view of the heavens, as was so tellingly demonstrated by Galileo Galilei (1564-1642) in 1610.

In the chequered history of astronomy — what the German poet Heinrich Heine (1797-1856) called 'the old, everyoung science' — the middle of the nineteenth century is a watershed.

The work of Joseph Fraunhofer (1787-1826) — who in 1815 obtained a detailed map of the solar spectrum — and of Gustav Kirchhoff (1824-1887) — who interpreted it in 1859 — showed that the starlight was amenable to an analysis in the laboratory, and could tell us something about the nature of the star itself.

The stars were the same, but their message changed. So far, a beam of light received from a star had merely told us where the star was and how it looked. But now starlight would tell *what* the star was : It was the birth of 'physical astronomy' or astrophysics. And when in 1920 Megh Nad Saha (1893-1956) showed that the spectra of the light from the stars could be understood in terms of the physical conditions in the stellar atmospheres, using simple, well-known physical laws, suddenly man had the whole cosmos as his laboratory.

Now-a-days, of course, unfetterred by the limits of the human eye or the earth's atmosphere, we can observe the universe in the whole range of electromagnetic spectrum — from the gamma and X-ray to the infrared and radio regions. Recently it has even become possible to set up observatories in space, where the stars do not twinkle.

New discoveries, new insights, and new results at invisible wavelengths and from space have not rendered the good old ground-based optical astronomy redundant. On the contrary, they have invested it with a new thrill and a sense of expectancy.

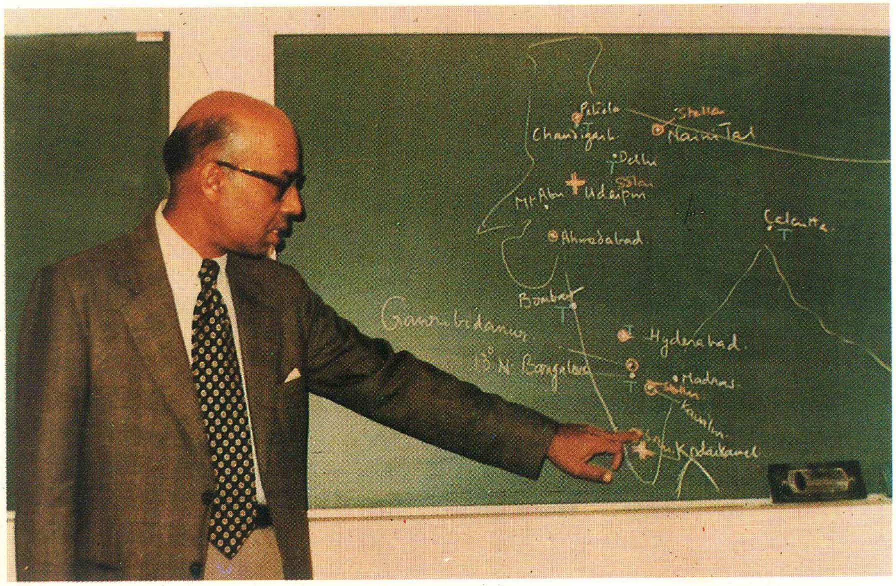
Indian Institute of Astrophysics

Indian Institute of Astrophysics is an institution devoted to research in, and development of, astronomical sciences. Its facilities are spread over four centres: Bangalore, Kodaikanal, Kavalur, and Gauribidanur.

The optics and electronics laboratories, mechanical workshop, and the administrative offices are at Bangalore. Also at Bangalore is the theory group working at various aspects of astrophysics and cosmology.

The Institute has prepared high-precision optics not only for its own use but also for institutions like the defence laboratories at Bangalore and Hyderabad; Indian Space Research Organization, Thumba and Sriharikota; Space Applications Centre, and Physical Research Laboratory, Ahmedabad; National Aeronautical Laboratory, Bangalore; and Tata Institute of Fundamental Research, Bombay.

Solar research facilities are at Kodaikanal, stellar at Kavalur; whereas the decametre wave radio telescope (run jointly with Raman Research Institute) is located at Gauribidanur.



Kodaikanal observatory

The sun, by no means a spectacular object as stars go, is still the star closest to us. Light from it takes only eight and a half minutes to reach the earth; the next nearest star, Proxima Centauri, is four light-years away. The sun's nearness makes it amenable to close scrutiny, so that we can know the star that sustains life on the earth, and learn about other stars which are like the sun.

The apparently unchanging sun can be rather quite active, with the activity taking about 11 years to go from one maximum to the next. The most conspicuous sign of solar activity is the sunspots which occur on the solar surface, or the photosphere. Sunspots are dark areas of intense magnetic fields, surrounded by rather bright large areas called plages. Hand in glove with the sunspots are the solar flares, which are large explosions on the surface of the sun and release visible light, radio waves, X-rays, and high speed atomic particles.

Above the photosphere lies the chromosphere, from which rise large clouds of dense cool gas called prominences.

The outermost layer of the sun's atmosphere is the corona, extending all the way to the earth, and visible in its full glory at the time of a total solar eclipse, which a solar physicist would not miss, wherever it occurred.

If we look at the sun in white light, we shall see only the surface and sunspots. To spot other features, we have to see the sun through special filters.

An important tool in solar research is a spectroheliograph which produces photographs of the sun in a single colour, called spectroheliograms. Kodaikanal has three spectroheliographs. The oldest, in use since 1904, produces pictures in the violet, K-line of ionized calcium, and is used to photograph the solar disc and prominences, every day. The second one made at the observatory in 1911 takes daily pictures of the disc in the red line of hydrogen (called H-alpha). The K-line pictures tell us about the upper layers of the chromosphere, whereas the H-alpha pictures tell us about the lower chromosphere. The third spectroheliograph, constructed in the 1960s, can produce a picture of the sun in any chosen colour.

White-light photographs, 20 cm in diameter, of the sun are taken every day with the photoheliograph made out of a 6 inches (15 cm) aperture telescope (by Lerebours & Secretan of Paris) acquired at Madras in 1850. White-light photographs are used to study sunspots, which give us information about the solar magnetic fields and solar rotation.

The pictures of the sun in white light, in K-line, and in H-alpha are exchanged with those from observatories all over the world so that a year-long record of the sun can be kept. This uninterrupted long series of photographs is a priceless record of solar activity. Only two other institutions in the world, Meudon observatory, Paris, and Mount Wilson observatory, USA, can boast of a similar collection.

Solar flares, and other quick-changing solar phenomena, are regularly monitored with a Hale spectrohelioscope obtained in 1934 as a gift from Mount Wilson observatory.

The best clues to the happenings on the surface of the sun, as indeed on all stars, come from spectral analysis. The main facility at Kodaikanal is the solar tower, in regular use since 1962. The 11 metre high tower has an arrangement of mirrors which directs sunlight into a 60 metre long underground tunnel, where a lens forms a stationary image of the sun, 34 cm in diameter, showing in fine detail the solar features. A spectrograph then produces a high resolution, high dispersion spectrum of the sunlight.

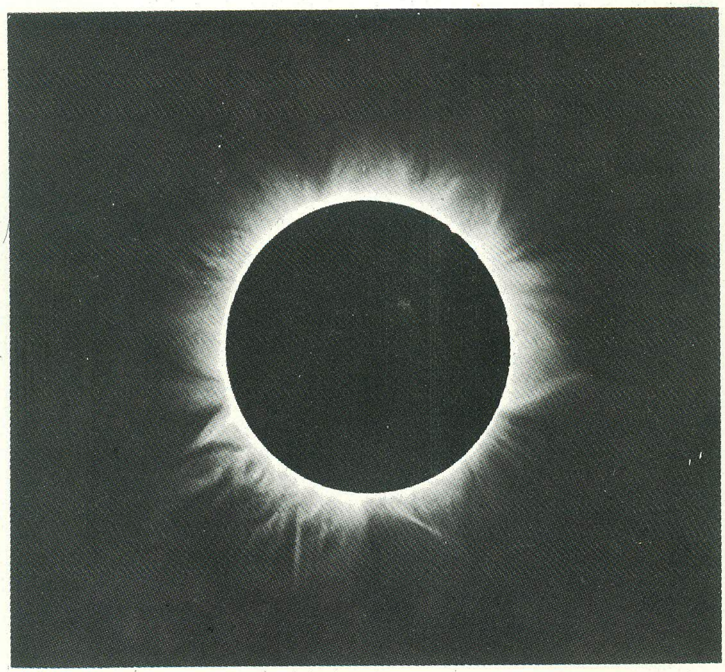
An examination of the solar spectra tells us about the strong magnetic fields in the sunspots, about velocity fields, about the rotation of the sun, and how solar features like plages, flares, prominences, etc., change with time. With the Kodaikanal spectrograph we can detect magnetic fields down to a few gauss, and gases moving with a speed as low as 100 metres per second.

Total solar eclipses provide an excellent opportunity to study the solar corona. No wonder, expeditions to observe total solar eclipses remain an important part of the Institute's scientific program.

Kodaikanal also has an 8 inches (20 cm) aperture telescope by Troughton & Simms of London, of 1866 Madras vintage, which is used for studying comets, and for visitors.

Observations of the earth's magnetic field are being made at Kodaikanal since 1949; and since 1952 ionosphere is being studied by regularly sending radio waves up to it and receiving them back after their reflection from the ionosphere.

Kodaikanal's location near the magnetic equator (barely half a degree north) makes it eminently suitable for the study of equatorial ionosphere.



Solar corona during the eclipse of 1980 February 16, photographed at Hosur, near Hubli (Karnataka).

Vainu Bappu observatory, Kavalur

Kavalur has an array of telescopes of various apertures 15 inches (38 cm); 30 inches (75 cm); 40 inches (1 metre), commissioned in 1972; and the new computer controlled 2.3 metre aperture, Vainu Bappu telescope, whose tube is mounted at the centre of a yoke attached on its north side to a massive horse-shoe. The telescope can easily resolve a 25 paisa coin kept forty kilometres away. A VAX 11/780 computer is at hand for on-line analysis of data, including image processing. And now a 45 cm aperture Schmidt telescope has been commissioned for wide-field studies.

The small 38 cm telescope — made in the backyards of Kodaikanal observatory using a mounting borrowed from a 90 year old telescope — is the one that in 1968 brought astronomy to the sleepy little hamlet of Kavalur in the Javadi hills. From it to the sophisticated 2.3 metre telescope that would have done any country proud, Kavalur has indeed come a long way in a short span of 18 years.

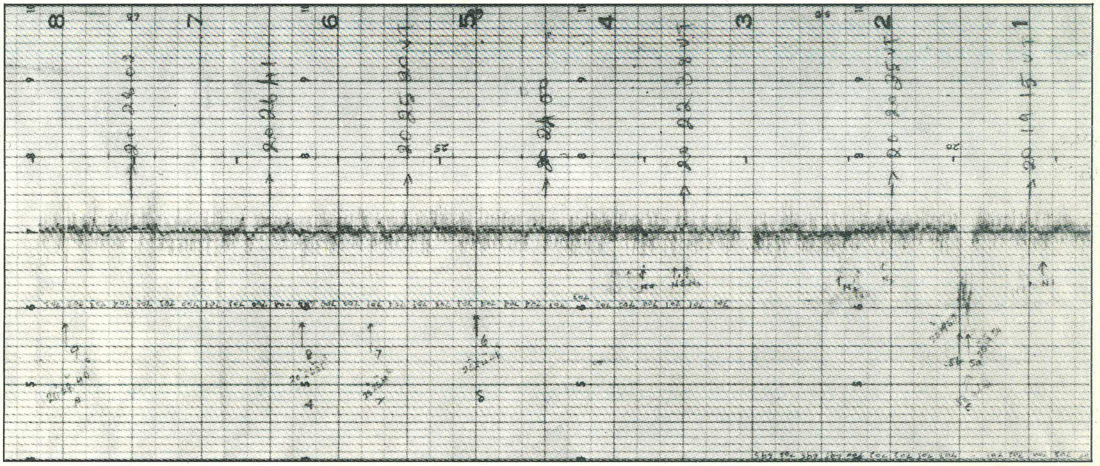
The observatory and the 2.3 metre telescope were named after M. K. Vainu Bappu (1927-1982) by the prime minister Rajiv Gandhi, on 6 January 1986.

To record stellar spectra, a number of spectographs are available for use with the 75 cm and 1 metre telescopes. Many record the spectra directly on the old-fashioned photographic emulsions, whereas others intensify the star image tenfold before recording it. The 1 metre telescope has for use a microprocessor-controlled photoelectric spectrum scanner, which is essentially a spectrograph used along with a photo-multiplier. A recent acquisition is a computer-controlled intensified image dissector spectrum scanner (IDS).

The spectra taken with various instruments are used to study the chromospheres of stars; the envelopes of peculiar stars; novae and supernovae; and the chemical composition of stars.

One can study the spectra of nearby objects, that are in the solar system, like the planets, their satellites, and occasional comets. The Doppler shifts in the spectral lines make it possible to measure the speeds of the stars relative to us, especially of those binary stars which are too close together to be separately seen.

Cameras can be attached to the telescopes to photograph heavenly

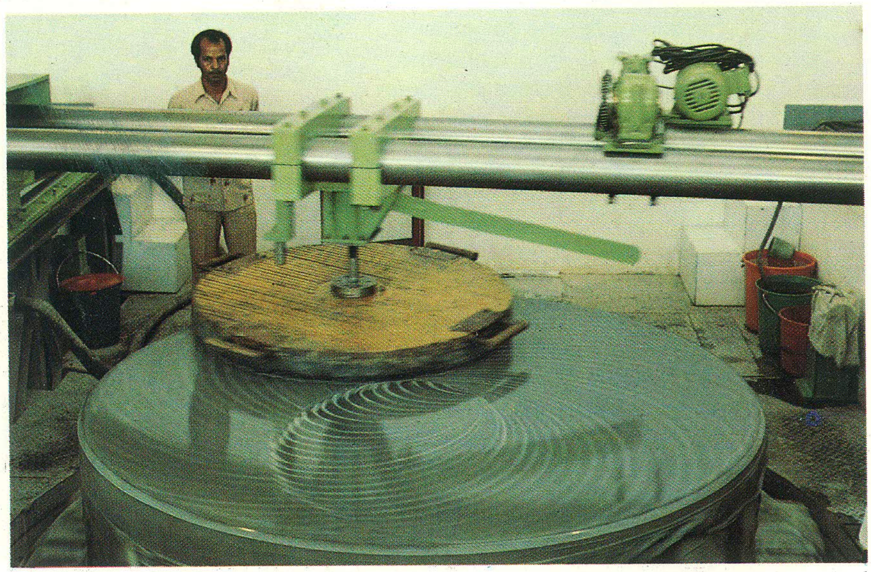


A part of the original observational data, from which the rings of Uranus were discovered on 10 March 1977.

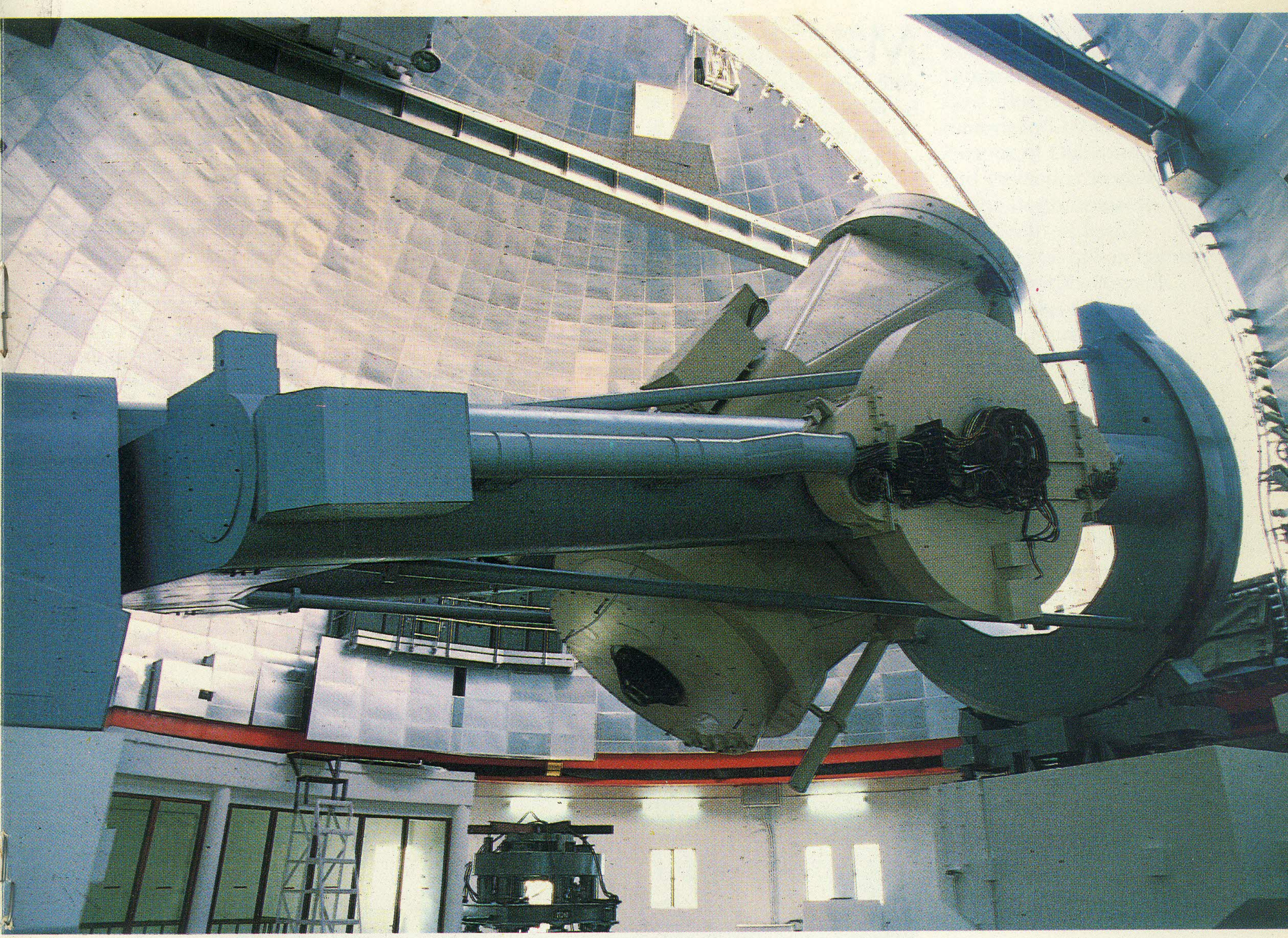
bodies. At times, we use a thin prism to obtain 'microspectra' of all the objects in the field of view. These microspectra are then used to survey different types of objects, such as late-type stars, emission-line stars, and quasars. Ordinary astronomical photography enables us to find out how light is distributed on the surface of objects which form an extended image, like the nebulae and galaxies.

The brightness of stars is measured both photographically and photoelectrically. Photoelectric photometres give more accurate results, but photographs can spot fainter objects. All the telescopes have their photoelectric photometers; the one used at the 1 metre telescope is automated with the microprocessor, making it all the more versatile. An exciting event to study is when the bodies in the solar system accidentally occult distant stars. Atmosphere on Jupiter's satellite Ganymede; the rings around Uranus; and the outer rings of Saturn were all discovered from Kavalur by the occultation technique. This technique also gives the sizes of asteroids, the diameters of stars, and the separation between stars in double-star systems.

New technologies are always making astronomy more exciting: Charge-coupled devices have an uncanny knack of recording faint light signals, while speckle interferometry enables us to get rid of the blurring caused by the earth's turbulent atmosphere, and construct true images of the cosmic objects. When high technology and human ingenuity join hands, sky is the limit.



The mirror of the Vainu Bappu telescope being ground at the optics laboratory of the Institute.



The 2.3 metre, Vainu Bappu telescope, seen from the east.

Gauribidanur radio telescope

Many cosmic bodies, including the sun, emit radio waves which can be received on the earth. The radio eye unveils many mysteries of the universe.

Indian Institute of Astrophysics and Raman Research Institute jointly run a decametre-wave radio telescope at Gauribidanur, in the Kolar district of Karnataka.

Commissioned in 1976, the telescope is a T shaped array of 1000 dipoles fixed on 3500 wooden poles of varying heights to allow for the sloping terrain, giving an effective collecting area of 25000 square metres. The T—with 1.4 km long east-west arm and half a kilometre long south arm — receives radio waves sent out by astronomical objects at a rather low frequency of 34.5 megahertz, that is, a wavelength of 8.7 metres.

An important result from the telescope has been the recording of radio waves coming from the apparently vacant space between the galaxies in the distant Coma cluster.

The Gauribidanur telescope is being used to detect radio emission from as diverse objects as the outskirts of the hot solar corona and the tiny pulsars. It is also used to probe the structure of the supernova remnants, the debris of exploding stars; and of the multitude of regions of ionized hydrogen that are present in our Milky Way galaxy.

The south arm of the Gauribidanur radio telescope, seen from the south.

Brief history

Indian Institute of Astrophysics traces its history back to the year 1786 when William Petrie (died 1816), an officer of the East India Company, set up a private observatory at his residence at Egmore, Madras. The observatory was taken over by the company in 1789, thanks to the efforts of Michael Topping; and the new campus at Nungambakkam was ready by 1792 end.

The observatory was set up to provide navigational assistance to the comapany, and other ships; to help determine the longitudes and latitudes of the ever expanding territories of the company; and to promote astronomy.

The oldest observation on record is dated 5 December 1786. Noted in a manuscript, it records the longitude and latitude of Masulipatam Fort. The value for the observatory longitude deduced in 1807 by John Warren (1769-1830), the acting Astronomer, continued to be used in all official maps till 1905.

To begin with, the observatory was rather modestly equipped. For the first more-than-forty years of its existence it did not have an object glass of as much as an inch and a half in aperture.

The observatory acquired in 1830 a 5 feet focus transit instrument and a 4 feet diameter mural circle, both made specially for it by Dollond. From observations made between 1831 and 1843 with these instruments, Thomas Glanville Taylor (1804-1848) prepared his celebrated Madras catalogue which listed the positions of 11015 stars, and formed the basis of British Association's 1845 catalogue. Taylor's catalogue was revised and reissued in 1893.

The observatory obtained its first fixed telescope in 1850, thanks to William Stephan Jacob (1813-1862).

It was a 6 inches aperture equatorial telescope by Lerebours & Secretan of Paris. This telescope was remodelled by Grubb Parsons of Dublin in 1898, and erected at Kodaikanal (in the north dome) in 1900. With its lenses changed it is still in harness — as a photoheliograph. This and the 8 inches aperture equatorial telescope by Troughton & Simms of London, got in 1866, were the main instruments with which Norman Robert Pogson (1829-1891) discovered from Madras five minor planets and six variable stars. After Pogson's death the 8 inch telescope fell increasingly into disuse, till it was rehabilitated in 1960 by Manali Kallat Vainu Bappu (1927-1982) at Kodaikanal (in the south dome).

Madras observatory teams observed the 1868 and the 1871 total solar eclipses, and the annular eclipse of 6 June 1872. It was at the 1872 eclipse that the spectrum of the chromosphere (the flash spectrum) was recorded, by Pogson, the first time ever at an annular eclipse.

By the later half of the nineteenth century a number of observatories had sprung up in Europe to study the new science of solar physics. However the European climate, specially English, was such that the observations were often interrupted, and low altitude of the winter sun made fine work impossible. For England, it was natural to think of India with its bright sunshine as prime location for solar studies.

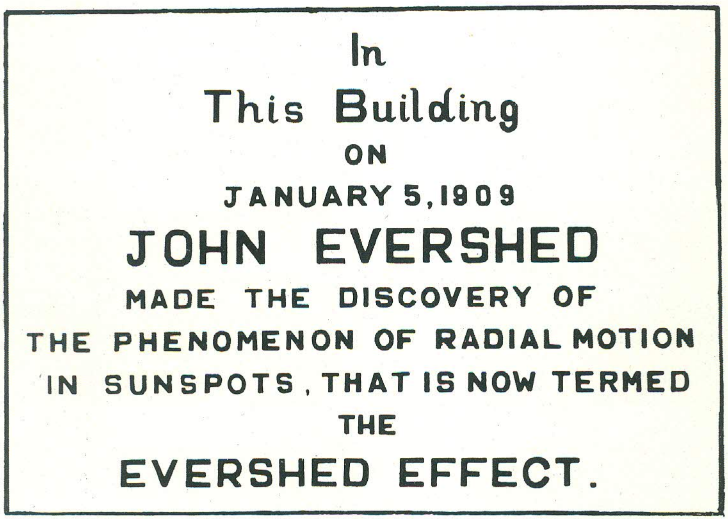
Finally, towards the close of the nineteenth century, a solar physics observatory was set up at Kodaikanal, divesting Madras of all astronomical activity ; and transferred from Madras government to the government of India.

Kodaikanal observatory started work in 1900. A spectroheliograph made by Cambridge Scientific Instruments Company arrived in 1904, and John Evershed in 1907.

In 1909, from the photographs of the sunspot spectra taken with a spectrograph he himself had made, Evershed discovered that there is radial outflow of gases in a sunspot. This effect is now known as Evershed effect.

Solar photography and spectroscopy continued to flourish at Kodaikanal, with an occasional comet or nova breaking the monotony. In early 1960 the obsevatory acquired a solar tower telescope for fine spectroscopic work.

Not surprisingly, stars had to play second fiddle to the sun at Kodaikanal, having to rest content with nothing more than a second-hand 20 inches (50 cm) aperture reflector (Bhavnagar telescope) which apparently had seen better days.



Plaque installed in 1975 at Kodaikanal to commemorate the discovery of the Evershed effect.

Vainu Bappu who took over as director in 1960 immediately set out to remedy the situation.

Efforts were launched to choose a good site for putting up bigger telescopes; and regular observations began at Kavalur in November 1968 with a home-made 15 inches (38 cm) aperture telescope. A 1 metre telescope by Carl Zeiss Jena was installed in 1972, the observatory having in the meantime — in 1971 — become an autonomous research institute, and renamed Indian Institute of Astrophysics.

The 1 metre telescope was used to make three singular discoveries in the solar system: In 1972 atmosphere was detected around Jupiter's satellite Ganymede; in 1977 rings were discovered around Uranus; and in 1984 a thin ring around Saturn was spotted.

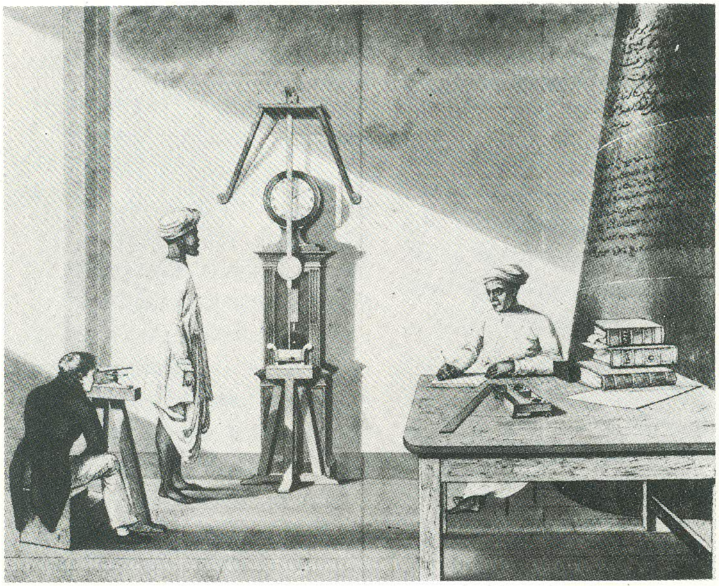
In 1976, the Institute and Raman Research Institute commissioned a decametre-wave radio telescope at Gauribidanur near Bangalore.

Vainu Bappu's swansong was the 2.3 metre aperture telescope, designed and built within the country. A 'blank' of Zerodur glass, purchased from the West German firm of Jenaer Glasswork Schott was painstakingly transformed into a smooth paraboloid mirror, while the mechanical parts designed by Tata Consulting Engineers, Bombay, were fabricated by the Pune-based Walchandnagar Industries. Scientists and engineers from the Institute have ensured that the telescope will effortlessly scan the skies and precisely point at a chosen cosmic object.

In a befitting tribute to Vainu Bappu, the prime minister Rajiv Gandhi, at a function held at Kavalur on 6 January 1986, named the observatory Vainu Bappu observatory; and the 2.3 metre telescope Vainu Bappu telescope.

With the 2.3 metre telescope safely under its belt, Indian Institute of Astrophysics—now a part of government of India's department of science and technology — is poised for a better and deeper understanding of the cosmic environment.

1821 : John Goldingham, the director of Madras observatory, experimenting with a pendulum. Thiruvenkatachary (left) and Srinivasachary (right) are the two assistants. (Philosophical Transactions 1822).



1986 : Comet Halley photographed March 19, at Kavalur with the new, 45 cm aperture Schmidt telescope

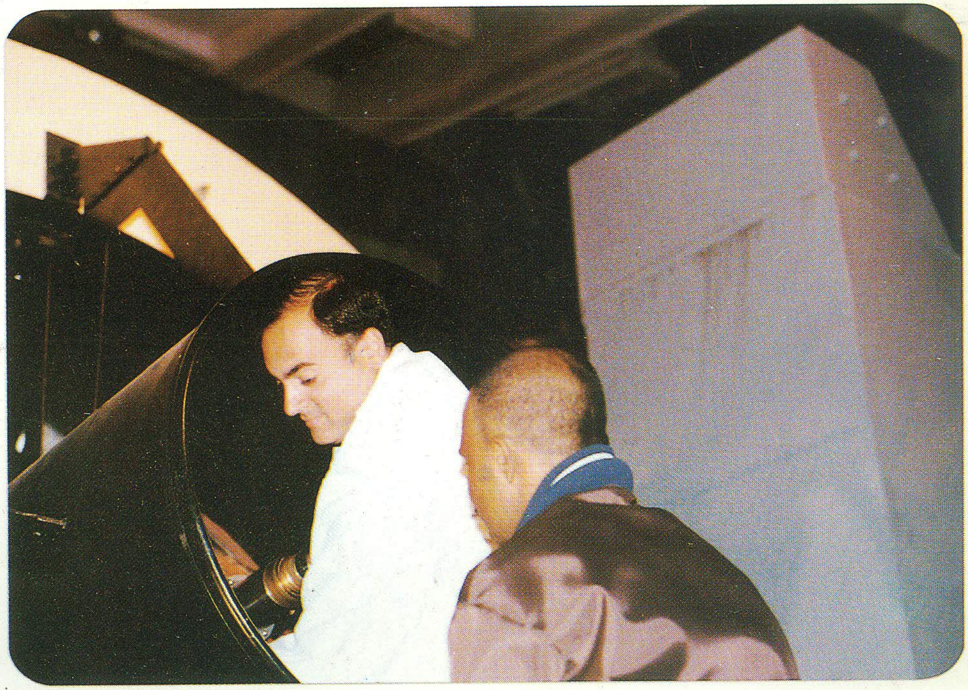
List of directors 1786-1986

William Petrie	1786-1789
Michael Topping	1789-1796
John Goldingham	1796-1805 1812-1830
John Warren	1805-1812 (acting)
T. G. Taylor	1830-1848
W. S. Jacob	1849-1858
J. F. Tennant	1859-1860
N. R. Pogson	1861-1891
C. Michie Smith*	1891-1910
John Evershed	1911-1923
Thomas Royds	1923-1937
A. L. Narayan	1937-1946
A. K. Das	1946-1960
M. K. Vainu Bappu†	1960-1982
J. C. Bhattacharyya	1982-

* Moved to Kodaikanal in 1899
† Moved to Bangalore in 1976

Prime minister Rajiv Gandhi names the 2.3 metre telescope after M.K. Vainu Bappu.

The prime minister getting into the prime focus cage of the Vainu Bappu telescope.



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Decametre radio-wave telescope
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Gauribidanur 569 210
Kolar Dist, Karnataka.

A view of the Vainu Bappu observatory, Kavalur, from the north.

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