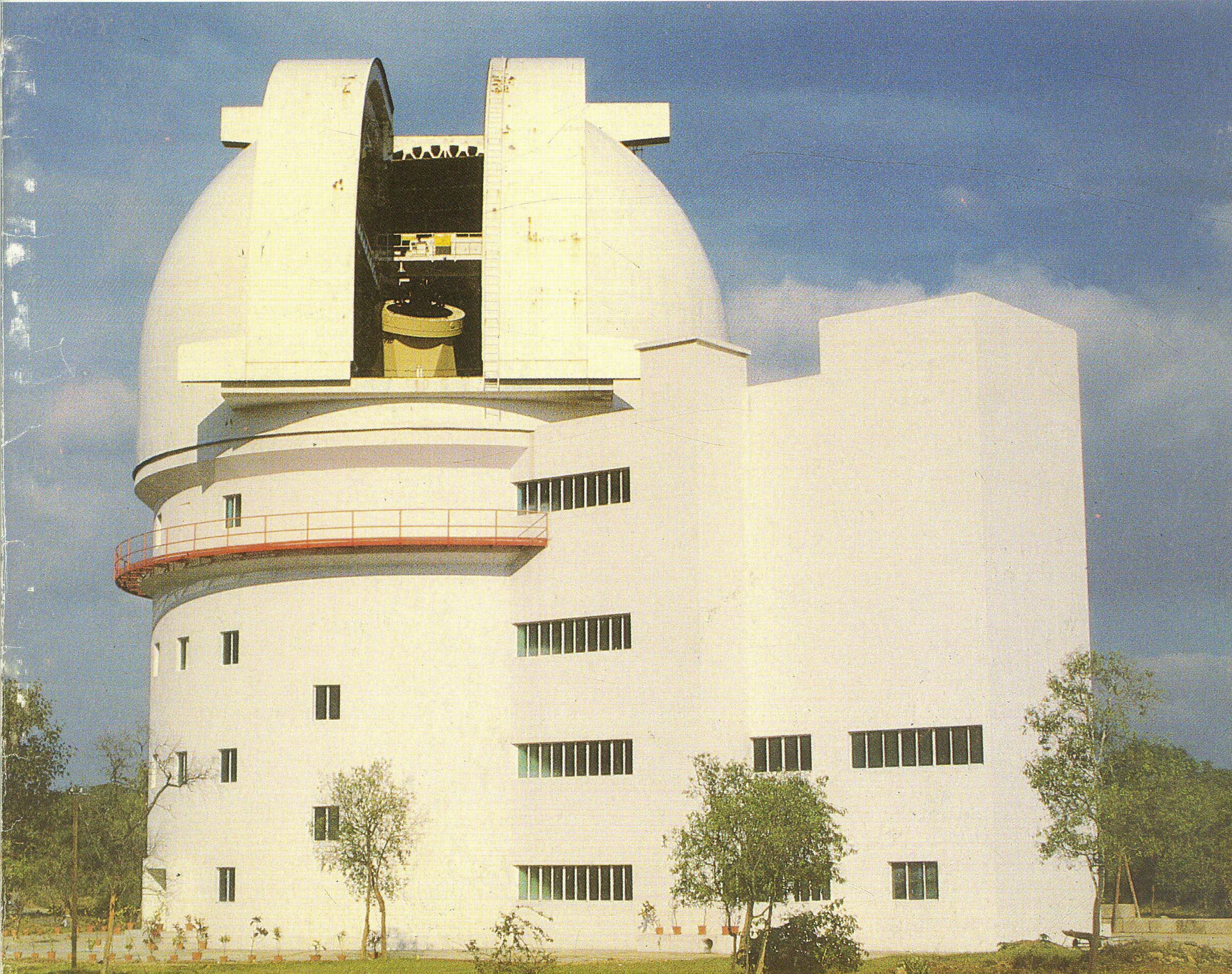
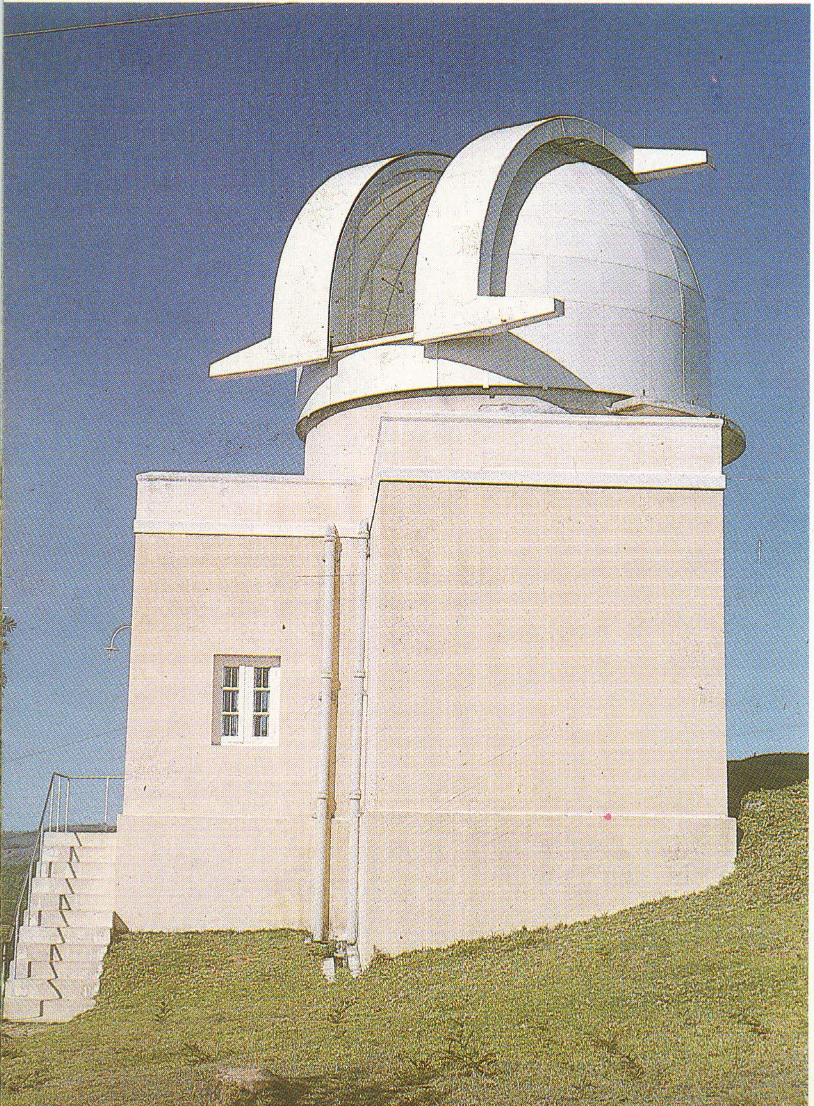
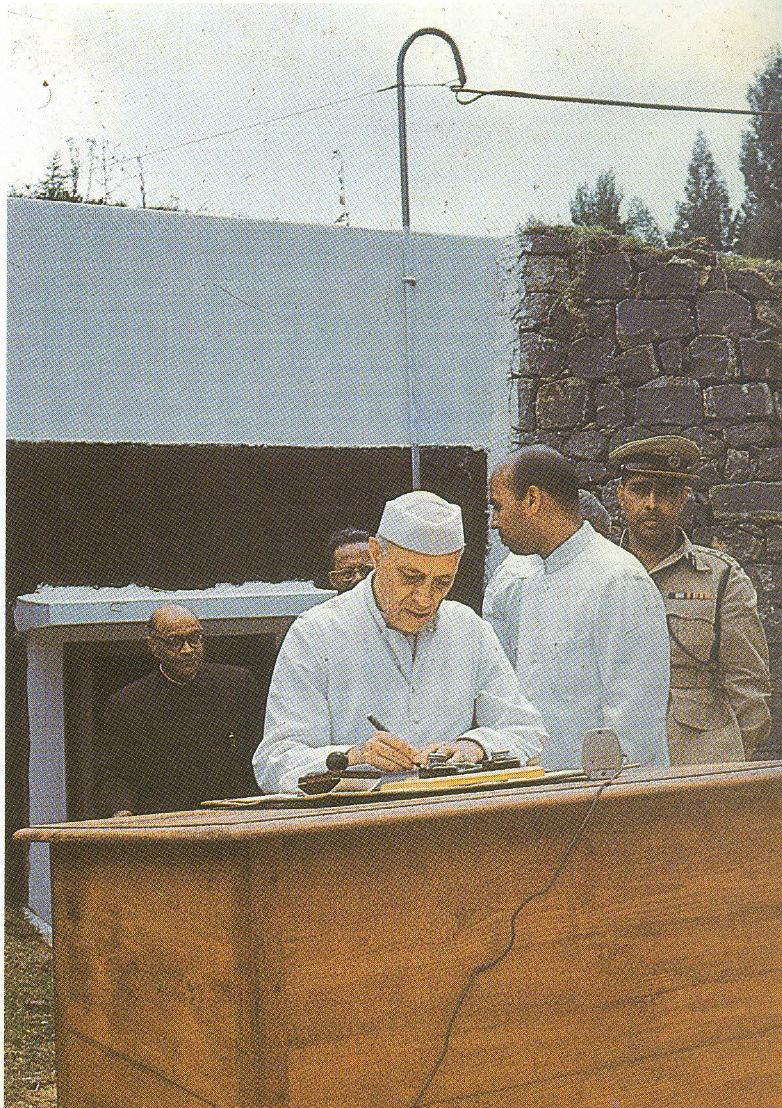
INDIAN INSTITUTE OF ASTROPHYSICS



The solar tunnel 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.



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 a belief in the role of planets as divine messengers and from the down-to-earth problem of making a sensible calendar to keep time.

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.

In 1815 Joseph Fraunhofer (1787-1826) obtained a detailed map of the solar spectrum. Gustav Kirchoff (1824-87) who interpreted it in 1850 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. It has even become possible to set up observatories, including an optical one, 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.

Front cover

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

Written and produced by Dr R K Kochhar for Indian Institute of Astrophysics. Text and photographs in this brochure can be reproduced without permission by acknowledging the source.
4 1994 January

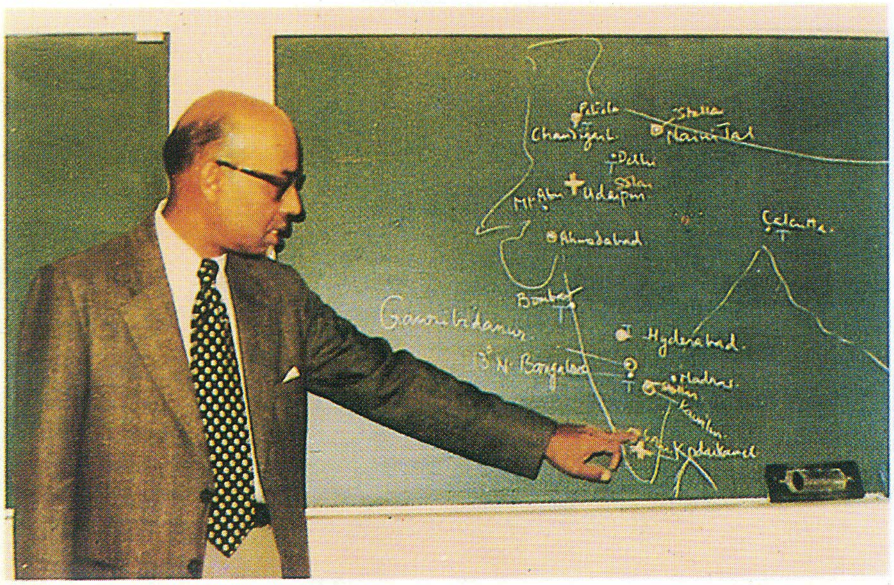
Indian Institute of Astrophysics

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.

Facilities at Kodaikanal are devoted to solar research, while Kavalur specializes in night-time astronomy. There are two collaborative facilities at Gauribidanur: a decametre-wave radio telescope (run jointly with the Raman Research Institute) and a gravitation experiment laboratory (run jointly with the Tata Institute of Fundamental Research). The administrative offices of the Institute are located at Bangalore, as also the optics and electronics laboratories and the mechanical workshop.

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

The theory group, based at Bangalore, tackles a wide variety of research problems in theoretical solar physics, astrophysics and cosmology. Specific areas include solar magnetohydrodynamics, solar interior, radiative transfer, galaxy dynamics, relativistic astrophysics, gravitation theory, early universe, active galactic nuclei and quasars, compact objects like black holes, white holes and pulsars, and astroparticle-physics. An international collaborative experiment seeks to settle the important question whether neutrino is its own antiparticle.



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. Sometimes rearrangement of the magnetic field in sunspot regions produces 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 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.

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. This database has helped obtain a better understanding of the long-term behaviour of sun's magnetic field, rotation, flares and other phenomena.

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 tunnel telescope acquired in 1958. 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 spectrogrpah 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. An event to look forward would be the total solar eclipse of 24 October 1995 visible from north and east India.

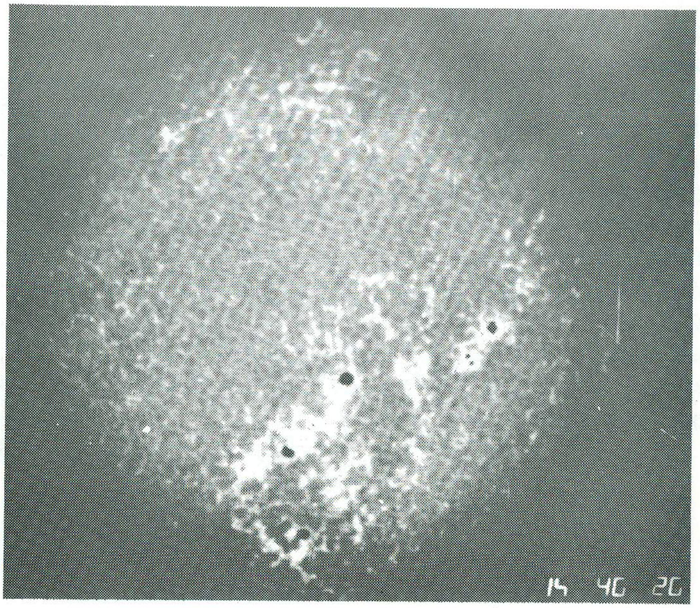
The icy continent of Antarctica is a solar physicist's delight, because the summer sun can be seen round the clock. During the ninth Indian expedition to Antarctica, 1989-90, Institute scientists installed a small, 10 cm, telescope, and photographed the sun in the light of the calcium K line for more than 100 hours at a stretch. From this, important clues have been obtained on factors affecting the life times of the large convective cells on the surface of the sun, which are technically known as supergranules.

Kodaikanal also has an 8 inches (20cm) aperture telescope by Troughton & Simms of London, of 1864 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.

A telescope has been made at the Institute which would be flown aboard an American rocket, for studying extreme ultraviolet radiation coming from the sun.



The sun as seen from the Antarctica. Photograph taken in the light of calcium K line on 8 January 1990 shows supergranules and bright plages around the dark sunspots.

Vainu Bappu observatory, Kavalur

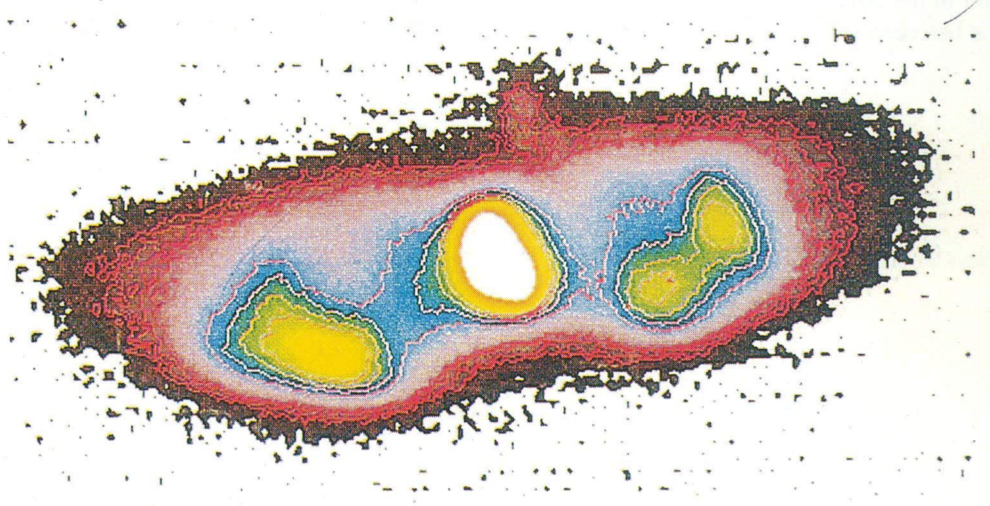
Kavalur has a covey of reflector telescopes of various sizes, headed by the 2.3 metre aperture Vainu Bappu telescope. The other telescopes are of apertures 1 m,75cm,and 38cm. There is in addition a 45 cm aperture Schimdt telescope for wide-field photography. The small 38 cm (15 inch) telescope, made in the backyard 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 come a long way in a short span of 25 years.

The observatory and the 2.3 metre telescope were named after Manali Kallat Vainu Bappu(1927-82) by Rajiv Gandhi, on 6 January 1986.

A telescope brings light from a distant object to a sharp focus.What transforms a telescope into a scientific instrument is the availability of accessories that permit scientific scrutiny of the focused light. A charge - coupled device(CCD) is a tiny chip of semiconducting silicon that is an electronic counterpart of the photographic film. Originally developed for use by the military, CCDs, supported by computer software, have the unerring knack of recording faint images. The first use of CCD in astronomy was in 1975 when an image of Uranus was obtained. Today a 1m telescope fitted with a CCD can see as far as a 4 m telescope could 20 years ago, when equipped with a traditional photographic plate.

Both the 2.3m and 1m telescopes at Kavalur are furnished with CCD detectors. In addition, a number of spectographs are available to record the spectra of celestial objects. Polarimeters enable one to determine the polarization of star light. Brightness of stars and galaxies can be measured using photometers. The two smaller telescopes, of 75 cm and 38 cm aperture, are dedicated to photometric observations of stars whose light shows variation with time.

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 a suspected outer ring of



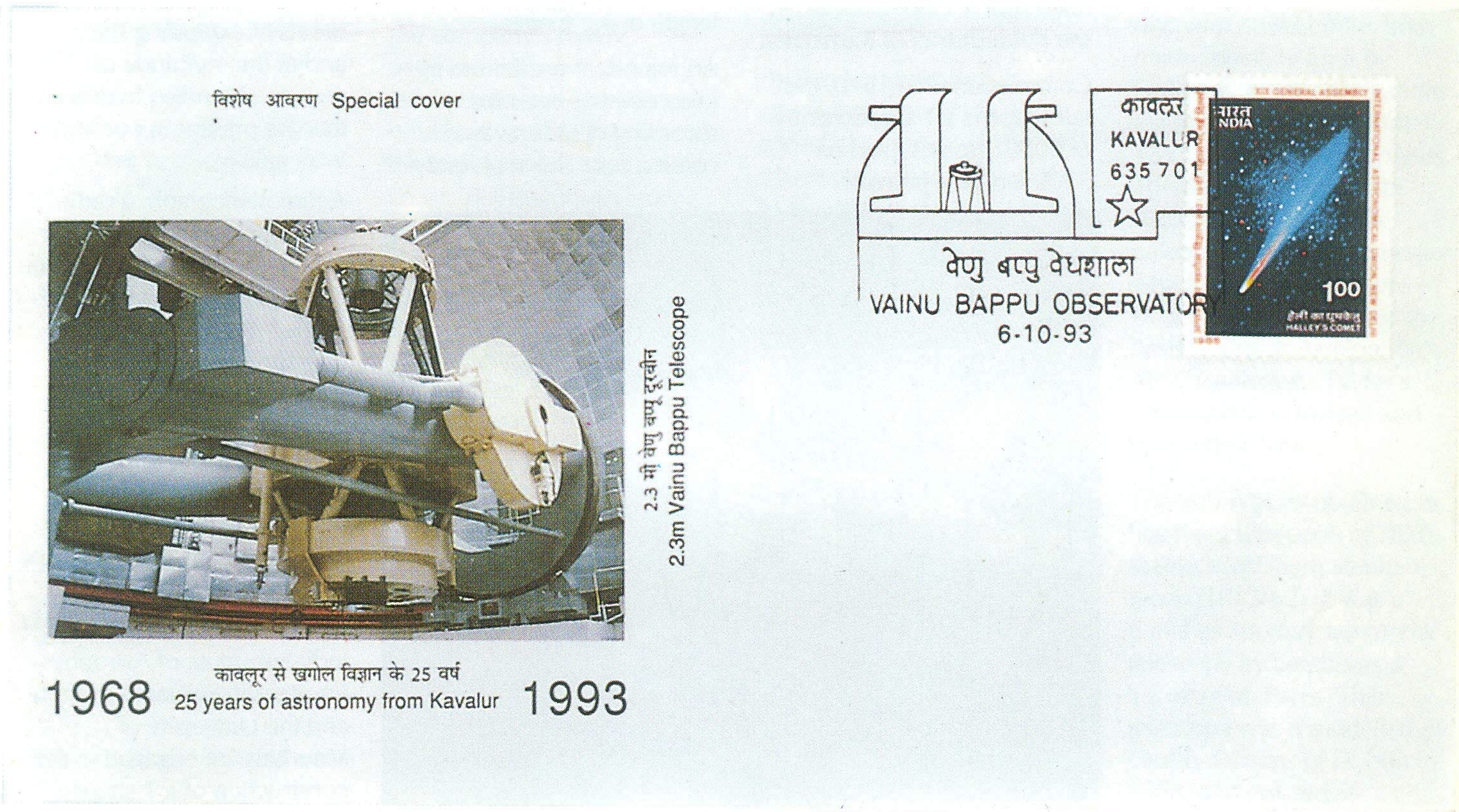
The Butterfly nebula, formally known as M2-9, imaged in the light of hydrogen-alpha line, using a CCD detector attached to the I m telescope. The two lobes on either side of the central blob are made of gas and dust. The central blob also of gas and dust hides a low-mass star which would soon evolve in to a white dwarf.

Saturn were all discovered from Kavalur by the occultation technique. This technique also gives the sizes of asteriods, the diameters of stars, and the separation between stars in double-star systems.

The Institute astronomers use facilities at Kavalur and elsewhere to study a wide spectrum of topics. Activity on the surface of stars, stellar mass loss, elemental abundances, and stellar chromospheres are studied with a view to understanding the physics of the stars. Other subjects of interest are binary stars; nebulae around certain stars, misleadingly named planetary nebulae; novae and supernovae (such as SN 1987 A) . Clusters of stars in our Galaxy and others provide important clues to formation of stars and their ageing. Matter in the almost empty space between stars also receives due attention. In addition, it has now become possible to investigate the properties of rather far-off galaxies. Giant regions of ionized hydrogen in other galaxies reveal that bursts of star formation have taken place in recent times, that is, during the last 10 million years or so. Many early-type galaxies also show signs of star formation.

New technologies are always making astronomy more exciting. 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.

A CCD image of a compact group of galaxies, technically known as Hickson group 37, taken with the 2.3 m Vainu Bappu telescope. The white dot to the left is a foreground star



A special cover brought out by the Institute on 6 October 1993, to mark 25 years of astronomy from Kavalur. The post office introduced a special cancellation on the day for regular use.

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.

A radioheliograph, a radio telescope dedicated to solar studies, is under construction at Gauribidanur. Made of T-shaped dipole arrays and operating in the frequency range 30-150 MGz, it will produce images of the solar corona at differing heights from the solar surface depending upon the frequency of observation. The telescope will have a resolution of about 5 arc minutes at 150 MHz.

Indian Institute of Astrophysics, Raman Research Institute and the University of Mauritius are engaged in the construction of a T-shaped metre-wave radio telescope in Mauritius (latitude 20°S). The telescope is already being used to map radio emission from regions around the centre of our Galaxy and from its southern parts.

The metre-wave radio telescope being built at Bras D'eau in north-east Mauritius.

Brief history

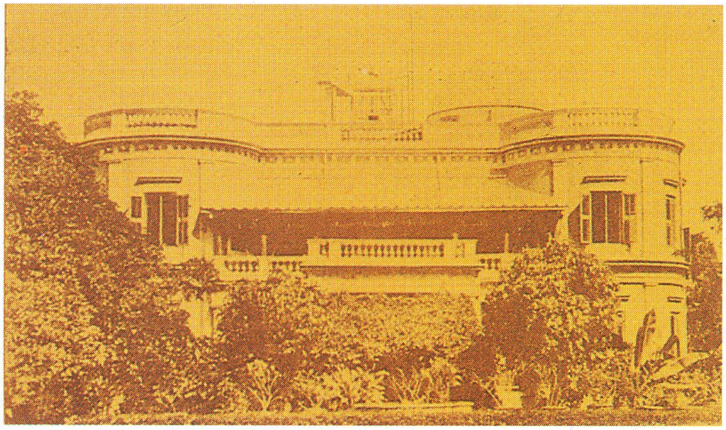
Indian Institute of Astrophysics traces its origin back to the year 1786 when William Petrie (died 1816), an influential and enlightened officer of the east India company, set up a small private observatory in his garden house at Egmore, Madras. The same year, Michael Topping (1747-96), the company's newly acquired trained astronomer-surveyor, set out on a badly needed survey of the treacherous Coromandel coast. Petrie's observatory was not the first modern observatory in India, but it led to bigger things. It provided a refernece meridian for Topping's coastal survey. In 1790, it was formally taken over by the company which used it as a nucleus to establish an observatory of its own, with Topping as the astronomer.

The Company's observatory buildings came up at Nungambakkam, Madras, in 1792. (This year has been often but wrongly quoted for the observatory's establishment).

The comapny's observatory at Madras was the first ever modern public observatory outside Europe.

As if to highlight its surveying connection, the oldest observation in the observatory records pertains to the coastal survey. Made by Topping on 5 December 1786, it determines the longitude and latitude of the Masulipatnam 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.



An undated photograph of the Madras observatory building. On top are two domes housing the 6 inch and 8 inch telescopes.

To begin with, the observatory was rather modestly equipped. For the first40 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 (1804-48) 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 Stephen Jacob (1813-62). 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 1864, were the main instruments with which Norman Robert Pogson (1829-91) discovered from Madras five minor planets and six variable stars. Pogson's assistant Chintamani Ragoonatha Charry (1838-82) discovered a variable star R Reticuli in 1867. This is the first recorded astronomical discovery by an Indian.

After Pogson's death the 8 inch telescope fell increasingly into disuse, till it was rehabilitated in 1960 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 weather, 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.

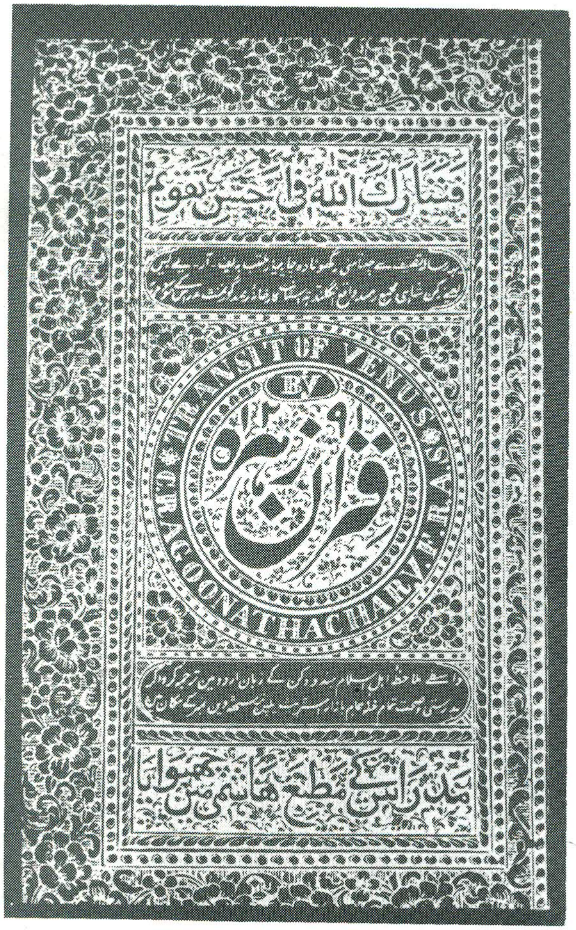
Finally, in 1899 a solar physics observatory was set up at Kodaikanal, under the control of the government of India. (One of the reasons given for the establishment of the observatory was that a study of the sun would help predict the behavious of the monsoons.)

A spectoheliograph 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 a radial outflow of gases in a sunspot. This effect is now known as the Evershed effect.

Solar photography and spectroscopy continued to flourish at Kodaikanal, with an occasional comet or nova breaking the monotony. In 1958, as a part of the international geophysical year celebrations, the observatory acquired a 15 inches aperture solar tunnel 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 (Bhavanagar telescope) of 1885 vintage which had seen better days at Pune under Kavasji Dadabhai Naegamvala (1857 - 1938).



The title page of a booklet in Urdu brought out by Chintamani Ragoonathachary on the occasion of the 1874 transit of Venus. (His name is spelt variously).

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.

In 1971, Kodaikanal observatory became an autonomous research institute with a new name: Indian Institute of Astrophysics. The Institute moved its head quarters to Bangalore in 1976, the transition having been made smooth by the hospitality of the Raman Research Institute.

In the meantime, in 1972, a 1 metre telescope by Carl Zeiss Jena was installed at Kavalur. It has been associated with two singular discoveries in the solar system. In 1972 atmosphere was detected around Jupiter's satellite Ganymade; and in 1977 rings were discovered around Uranus. In 1984 Kavalur reported the probable discovery of a thin outer ring around Saturn.

On 17 February 1988, a new minor planet was discovered, using the 45 cm Schmidt telescope. It has been named Ramanujan after the Indian mathematical genius Srinivasa Ramanujan (1887-1920). This is the first such discovery from India in this century.

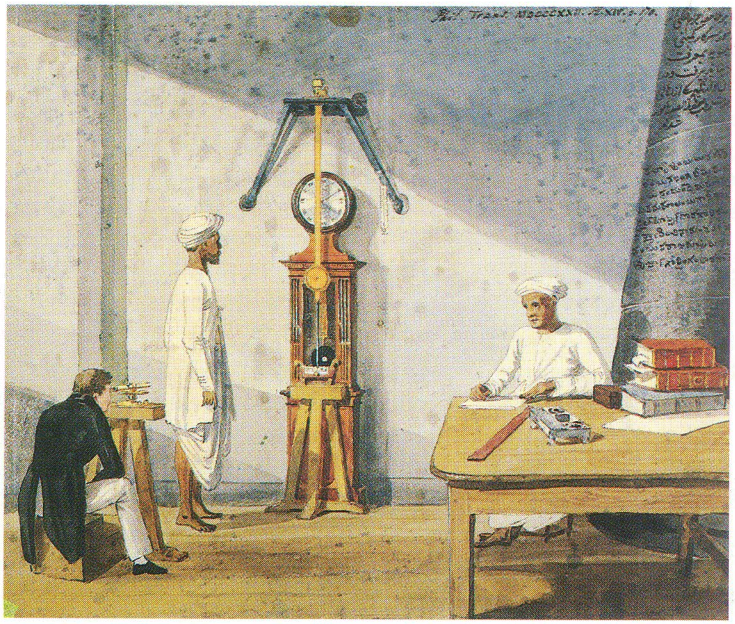
In 1976, the Institute and Raman Research Institute commisioned a decametre-wave radio telescope at Gauribidanur near Bangalore.

Vainu Bappu's swansong was the 2.3 metre aperture telescope, designed and built within the country. In a befitting tribute to Vainu Bappu, the prime minsiter 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. He also released (the first edition of) the Institute brochure. During 1986 and 1987, the Institute celebrated 200 years of its completion.

Indian Institute of Astrophysics , a part of government of India's department of science and technology, seeks a better and deeper understanding of the cosmic environment, by constantly updating its instruments and by training young astronomers.

When high technology and human ingenuity join hands, sky is the limit.

John Goldingham swinging a Kater's pendulum in front of a Haswell clock at Madras observatory, 1821. The assistants are Teroovencatachary (left) and Senavassachary (right). Partly visible in the right is the 18 ft high granite pillar, which can still be seen at Madras.

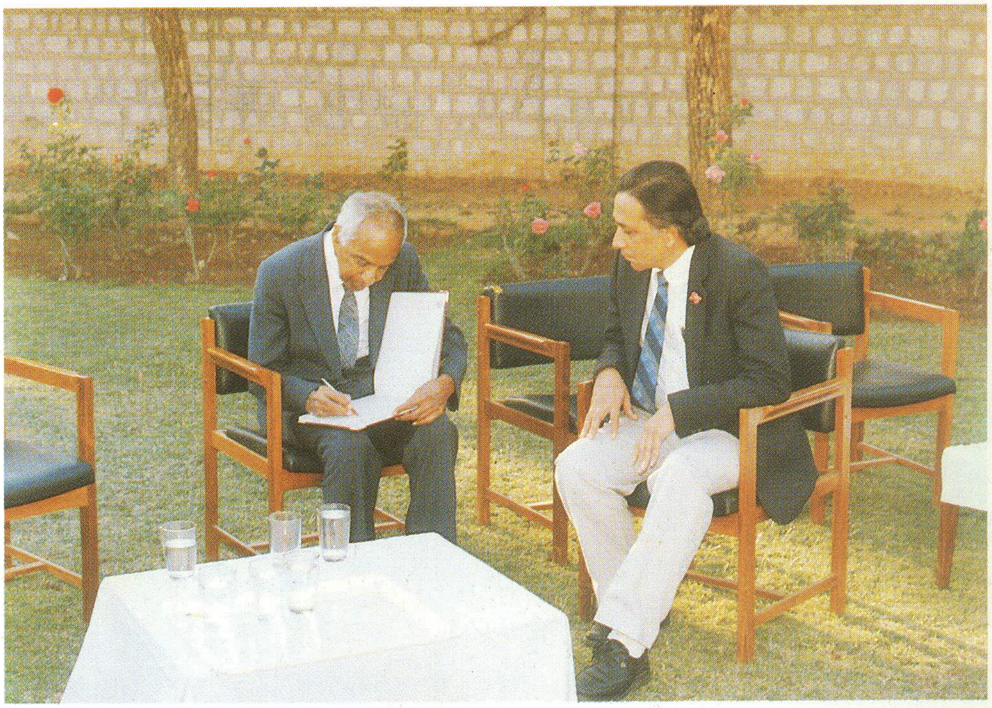


List of directors[1]

William Petrie	1786-1789
Michael Topping[2]	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[3]	1891-1910
John Evershed	1911-1923
Thomas Royds	1923-1937
A.L. Narayan	1937-1946
A.K. Das	1946-1960
M.K. Vainu Bappu[4]	1960-1982
J.C. Bhattacharyya	1982-1990
R. Cowsik	1992-

1 Excluding those who officiated for short periods.
2 Appointed company astronomer in 1790.
3 Moved to Kodaikanal in 1899.
4 Moved to Bangalore in 1976.

A sunshield panel for the radiometer of the INSAT II satellite. The metal surface has been specially polished to reflect almost the entire sunlight falling on it.



Subramanyan Chandrasekhar signing the visitor's book on 11 January 1993. To his left is Ramanath Cowsik.

- Indian Institute of Astrophysics, Sarjapur Road, Koramangala, Bangalore 560034
- Kodaikanal observatory, Indian Institute of Astrophysics, Kodaikanal 624103
- Vainu Bappu observatory, Indian Institute of Astrophysics, Kavalur, Alangayam 635701, North Arcot Ambedkar Dist, Tamilnadu
- Decametre wave radio telescope, Indian Institute of Astrophysics, Raman Research Institute, Gauribidanur 561210, Kolar Dist, Karnataka
- Gravitation experiment laboratory, BARC seismic array station, Gauribidanur - Hosur 561208, Kolar Dist, Karnataka

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

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